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ENCYCLOPÆDIA BRITANNICA.

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MEYAHOOON, a town of the Burman dominions, extending about two miles along the western margin of the Irrawaddy, and glittering at a distance with gilded spires. It has also many spacious convents. The vicinity is uncommonly productive in rice, of which large stores are kept here ready to be transported to any part of the empire where a scarcity occurs. Long. 95. 8. E. Lat. 18. 19. N.

MEYWAR, a very extensive district of Hindustan, in the province of Ajmeer, situated principally between the 25th and 26th degrees of north latitude, and occasionally named Chitore and Odeypoor. The general surface is hilly, but not mountainous, although it abounds in naturally strong positions. The productions of this territory are wheat, rice, sugar, barley, and other grains; besides which it has a good breed of camels and horses. The principal manufactures are matchlocks, swords, and cotton cloth. The principal towns are Odeypoor, Shapoorah, and Bilarah. The district is at present possessed by numerous petty rajpoot chiefs, who live in perpetual hostility with each other.

MEYRINGEN, a town of Switzerland, which, on account of its natural beauties, is visited by most persons who, to gratify their taste for picturesque scenery, visit that country. It is situated in the vale of Hosli, in the upper part of the canton of Berne. It stands on a mountain 1950 feet above the level of the sea, and is surrounded by the snow-covered pinnacles of the neighbouring hills. The town, though so high, is situated in a rich and well-cultivated valley, into which there are some of the most lofty and copious waterfalls from the surrounding heights. The most remarkable of these cascades is the Reichenbach, which forms seven successive falls, the first of which is the largest, being 300 feet in height; it falls into a basin, into which the sun rarely penetrates, and, when seen from below, exhibits, about noon, in fine weather, some surprising rainbows. The town itself contains only 650 inhabitants; but there are two large hotels generally well filled with strangers during the summer months. The whole valley and parish contain 4490 souls, whose chief occupation consists in making butter and cheese, their cows being nearly 4000 in number.

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MEZERAÏ, FRANÇOIS EUDES DE, a celebrated French historian, the son of Isaac Eudes, a surgeon, was born at Rye, in Lower Normandy, in 1610, and took the surname of *Mézerai*, from a hamlet near Rye. Having completed his studies at Caen, he discovered a strong inclination to poetry; but on proceeding to Paris, he was advised by one of his friends to apply himself to the study of politics and history, and procured the place of commissary at war, which he held during two campaigns. He then shut himself up in the college of St Barbe, in the midst of books and manuscripts; and, in 1643, published the first volume of the History of France, in folio. Some years afterwards, the other two volumes also appeared. In that work Mézerai surpassed all who had written the history of France before him, and was rewarded by the king with a pension of four thousand livres. In 1668 he published an Abridgment of his History of France, in three volumes quarto, which was well received by the public; but as he inserted in that work the origin of most of the taxes, with very free reflections, M. Colbert complained of it, upon which Mézerai promised to correct what he had done in a second edition. As his corrections, however, amounted rather to palliations than changes or retractations, the minister caused half of his pension to be suppressed. Mézerai complained of this in very severe terms, but the only answer he obtained was the suppression of the other half. Annoyed at this treatment, he resolved to write on subjects which could not expose him to such disappointments, and composed his treatise on the origin of the French, which did him much honour. He was elected perpetual secretary to the French Academy, and died in the year 1683. He is said to have been extremely negligent of his person, and so careless of his dress that he might have passed for a beggar rather than a man of letters. He was actually seized one morning by the *archers des pauvres*, or parish officers; a mistake which, so far from provoking, highly diverted him. He used to study and write by candle-light, even at noon-day in summer; and, as if there had been no sun in the world, always waited upon his company to the door with a candle in his hand. In regard to religion, he affected a species of Pyrrhonism, which, however, was not so much

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in his heart as in his mouth, and rather the effect of a contradictory humour than the result of conviction. This appeared from his last sickness; for having sent for those friends who had been the most frequent auditors of his licentious talk about religion, he made a sort of recantation, which he concluded with desiring them to forget what he might formerly have said upon the subject of religion, and to "remember that Mézerai dying was more to be believed than Mézerai living." The following is a list of the works of Mézerai, viz. 1. *Histoire de France*, 1643, 1646, 1651, in three vols. folio; 2. *Abrégé Chronologique de l'Histoire de France*, 1668, in three vols. 4to; 3. *Traité de l'Origine des Français*, Amsterdam, 1688, in 12mo; 4. *Une Traduction de l'Histoire des Turcs de Chalcondyle*, Paris, 1662, in two vols. folio; 5. *Une Traduction Française du Traité de Jean de Salisbury, intitulé La Vanité de la Cour*, Paris, 1640, in 4to; 6. *Traité de la Vérité de la Religion Chrétienne*, translated from the Latin of Grotius, Paris, 1644, in 8vo; 7. *Histoire de la Mère et du Fils*, that is, of Mary of Medicis and Louis XIII., Amsterdam, 1730, in 4to. A compilation entitled *Mémoires Historiques et Critiques sur divers points de l'Histoire de France*, has also been ascribed to Mézerai, though apparently without the slightest foundation.

MEZIERES, an arrondissement of the department of Ardennes, in France, extending over 364 square miles. It is divided into seven cantons, and subdivided into 99 communes, containing 69,294 inhabitants. The capital is the city of the same name situated on the river Meuse, by which it is separated from Charleville. In 1836 its inhabitants amounted to 4083. It has a strong citadel, and also a school for the engineers. Its fortifications are of great strength. Long. 4. 38. 1. E. Lat. 49. 45. 47. N.

MEZIRIAC, CLAUDE GASPARD BACRET SIEUR DE, one of the most ingenious men of the seventeenth century, was born at Bourg-en-Bresse on the 9th of October 1581. He was a good poet, an excellent grammarian, a great Greek scholar, and an admirable critic. He was well versed in the controversies both in philosophy and religion, and deeply skilled in algebra and geometry, of which he gave proof by publishing the six books of Diophantus, enriched with a very able commentary and notes. In his youth he spent a considerable time at Paris and also at Rome, where, in competition with Vaugelas, he wrote a small collection of Italian poems, amongst which there are imitations of the most beautiful similes contained in the first eight books of the *Æneid*. He also translated Ovid's *Epistles*, great part of which he illustrated with very curious commentaries of his own; and undertook the translation of Plutarch's works, with notes, which he had nearly brought to a conclusion, when he died, at Bourg-en-Bresse, in 1638, at the age of fifty-seven. He left behind him several works, the principal of which are, 1. *Problèmes Plaisans et Délectables qui se font par les Nombres*, Lyons, 1613, 1624, in 8vo; 2. *Diophanti Alexandrini Arithmeticonum libri sex, et de Numeris multangulis liber unus*, Gr. et Lat. Commentar. illustrat. Paris, 1621, in folio; 3. *Chansons dévotes et saintes sur toutes les principales fêtes de l'Année, et sur autres divers sujets*, Dijon, 1615, in 8vo; 4. *Les Epîtres d'Ovide, trad. en vers François, avec des Commentaires*, Bourg-en-Bresse, 1626, in 8vo.

MEZUZOTH, in the Jewish customs, certain pieces of parchment, which the Jews affix to the door-posts of their houses; taking that literally which Moses commanded them, when he said, "Thou shalt never forget the laws of thy God, but thou shalt write them upon the posts of thy house, and on thy gates." This expression apparently meant nothing more than that they should always remember the laws of their God, whether they came into the house or went out. But the Hebrew doctors imagined that their lawgiver meant something more. They pretend-

ed that, to avoid making themselves ridiculous, by writing the commandments of God without their doors, or rather to avoid exposing themselves to the profanation of the wicked, they ought at least to write them on a parchment, and to enclose it in something. They, therefore, wrote these words upon a square piece of parchment prepared on purpose, with a particular ink, and in a square kind of character. The Hebrew word *mezuza* properly signifies the door-posts of a house; but it is also applied to the roll of parchment now mentioned.

MEZZOTINTO, a particular manner of representing figures on copper, so as to form prints in imitation of painting in Indian ink. See ENGRAVING.

The invention of this art has usually been attributed to Prince Rupert. But Baron Heinikin, a judicious and accurate writer upon the subject of engraving, asserts, with great appearance of truth, that it was a Lieutenant-colonel de Siegan, an officer in the service of the landgrave of Hesse, who first engraved in this manner; and that the print which he produced was a portrait of the Princess Amelia Elizabeth of Hesse, engraved in the year 1643. Prince Rupert learned the secret from this gentleman, and brought it into England when he came over the second time with Charles II. Prince Rupert's print of an executioner holding a sword in one hand and a head in the other, a half length, from Spagnoletto, is dated 1658. This art has never been cultivated with success in any country but England.

The prince laid his grounds upon the plate with a channelled roller; but, about the same time, one Sherwin laid his grounds with a half-round file, which was pressed down with a heavy piece of lead. Both these grounding tools have for many years been laid aside; and a hand tool, resembling a shoemaker's cutting-board knife, with a fine crenelling on the edge, was introduced by one Edial, a smith by trade, who afterwards became a mezzotinto engraver.

Mezzotinto is very different from the common way of engraving. To perform it, the surface of the plate is raked, hatched, or punched all over with a knife, or instrument made for the purpose, first one way, and then the other, until the surface of the plate is entirely furrowed with lines or furrows, close and as it were contiguous to each other; so that, if an impression were then taken from it, it would be one uniform blot or smut. This being done, the design is drawn or marked on the same face; after which, the artists proceed with burnishers, scrapers, and other tools, to expunge and take out the dents or furrows in all parts where the lights of the piece are designed to be; and that more or less as the lights are to be stronger or fainter, leaving those parts black which are to represent the shadows or deepening of the draught.

As it is much easier to scrape or burnish away parts of a dark ground corresponding with the outline of any design sketched upon it, than to form shades upon a light ground by an infinite number of hatches, strokes, and points, which must all terminate with exactness on the outline, as well as differ in their force and manner, the method of scraping, as it is called, in mezzotinto, becomes much more easy and expeditious than any other method of engraving. The instruments employed in this kind of engraving are, cradles, scrapers, and burnishers.

In this engraving, the plate must be prepared and polished in the same manner as for other engravings, and afterwards divided equally by lines parallel to each other, and traced out with very soft chalk. The distance of these lines should be about one third of the length of the face of the cradle which is to be used, and these lines should be marked with capital letters, or strokes of the chalk. The cradle is then to be placed exactly between the first two lines, and passed forwards in the same direction, being kept as steady as possible, and pressed upon with a mode-

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rate force. The same operation must be repeated with respect to all other lines, till the instrument has thus passed over the whole surface of the plate. From the extremities of the other two sides, other lines must then be drawn, which, intersecting the first at right angles, will with them form squares; and the same operation must be repeated with the cradle as in the case of the first. New lines must then be drawn diagonally, and the cradle passed between them as before; and when the first diagonal operation is performed, the lines must be crossed at right angles, like the former, and the cradles passed between them in the same manner. The plates having undergone the action of the cradle according to the disposition of the first order of lines, a second set must be formed, having the same distances from each other as the first. But they must be so placed as to divide those already made into spaces one third less than their whole extent; that is, every one after the first on each side will take in one third of that before it. These lines of the second order must be marked with small letters, or lesser strokes, to distinguish them from the first; and the same treatment of the plate must be pursued with respect to them as was practised for the others. When this second operation is finished, a third order of lines must be made. By these means, the original spaces will be exactly divided into equal thirds; and the cradle must be again employed between those lines, as before. When the whole of this operation is finished, it is called *one turn*; but in order to produce a very dark and uniform ground, the plate must undergo the repetition of all these several operations for above twenty times, beginning to pass the cradle again between the first lines, and proceeding in the same manner through all the rest. When the plate is prepared with a proper ground, the sketch must be chalked on it, by rubbing the paper on the back with chalk; and it is also proper to overtrace it afterwards with black lead or Indian ink. The scraping is then performed by paring or cutting away the grain of the ground in various degrees, so that none of it is left in the original state, except in the touches of the strongest shade. The general manner of proceeding is the same as drawing with white upon black paper. The masses of light are first commenced; then those parts which go off into light in their upper part, but are brown below. The reflections are next entered upon, after which the plate is blackened with a printer's blacking ball made of felt, in order to discover the effect, and then the work is proceeded with, observing always to begin every part in the places where the strongest lights are to be.

The art of scraping mezzotintos has been applied to that of printing with a variety of colours, in order to produce the resemblance of paintings. The inventor of the method of doing this was Le Blon, a native of Frankfort, and pupil of Carlo Marata, between the years 1720 and 1730. It was established by the inventor upon this principle, that there are three primitive colours, of which all the rest may be composed by mixing them in various proportions; that any two of these colours being mixed together, preserve their original power, and only produce a third colour such as their compound must necessarily give, but if transparent colours be mixed, and three primitive kinds compounded together, they destroy each other, and produce black, or a tendency to it, in proportion to the equality or inequality of the mixture; and that if the three primitive colours be laid, either separately or upon each other, by three plates, engraved correspondently on these principles to the colouring of the design, the whole variety of tints necessary may be produced. The requisites, therefore, to the execution of any design in this method of printing are the following: 1. To settle a plan of the colouring to be imitated, showing where the presence of each of the three simple colours is necessary, either in its pure state or com-

bined with some other, to produce the effect required, and to reduce this plan to a painted sketch of each, in which not only the proper outlines, but the degree of strength, shall be expressed; 2. to engrave three plates according to this plan, which may print each of the colours exactly in the places where, and the proportion in which, they are wanted; 3. to find three transparent substances proper for printing with these three primitive colours. The manner in which M. le Blon prepared the plates may be briefly stated. The three plates of copper were first well fitted to each other with respect to size and figure, and grounded in the same manner as those designed for mezzotinto prints; and the exact place and boundary of each of the three primitive colours, conformably to the design, were sketched out upon three papers answering in dimensions to the plate. These sketches were then chalked upon the plates; and all the parts of each plate which were not to convey the colour to which it was appropriated to the print were entirely scraped away, as in forming the light of mezzotinto prints. The parts which were to convey the colours were then worked upon; and where the lightest or most diluted tints of the colour were to be, the grain in the ground was proportionally taken off; but where the full colour was required, it was left entire. In this, regard was had not only to the effects of the colour in its simple state, but also to its combined operation, either in producing orange-colour, green, or purple, by its admixture with one alone; and further, to its forming brown, gray, and shades of different degrees, by its co-operation with both the others. But though the greater part of the engraving was performed in the mezzotinto manner, yet the graver was employed occasionally for strengthening the shades, and for correcting the outline where it required great accuracy and steadiness. It was found necessary sometimes to have two separate plates for printing the same colour, in order to produce a stronger effect; but the second plate, which was used to print upon the first, was intended only to glaze and soften the colours in particular parts which might require it. As to the black and brown tints, which could not be so conveniently produced in a due degree by the mixture of the colours, umber and black were likewise used.

With respect to the order in which the plates are to be applied, it may be proper to observe, that the colour which is least apparent in the picture should be laid on first; that which is between the most and least apparent next; and that which predominates last of all; except where there may be occasion for two plates for the same colour, as was before mentioned, or where there is any required for adding browns and shades.

M. le Blon applied this art to portraits, and showed, by the specimens he produced, the possibility of its being brought, by further improvements, to afford imitations of painting which might have some value. It is, nevertheless, much better adapted to the simpler subjects, where there are fewer intermixtures of colours, and where the accuracy of the reflections and demi-tints are not so essentially necessary to the truth of the design, from the greater latitude of form and disposition of the colour, as in plants, anatomical figures, and some subjects of architecture. But perhaps plates engraved, or rather finished, with the tool, particularly with respect to the outline, would be better accommodated in some of these cases than those prepared only by scraping.

M. Cochin remarks, at the end of an account he has given of M. le Blon's manner, that although this ingenious artist confined his method principally to the use of three colours, yet, should this invention be again taken up and cultivated, there would be more probability of success in using a greater variety; and that several different kinds might be printed by one plate, provided they were laid on in their respectively proper places by printing-balls, which should

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be used for that colour only. His hint might, however, be very greatly improved by the further assistance of pencils, accommodated to the plates, for laying on the colours in the proper parts.

MGLIN, a circle of the Russian province of Tscherne-gow, extending in north latitude from 52. 49. to 53. 17. and in east longitude from 32. 37. to 33. 54. The capital is a city of the same name situated on the river Sudenka. It is one of the best built cities of the province, and contains 980 houses, with 5370 inhabitants, who carry on considerable trade in the productions of its vicinity, especially in hemp, which is conveyed by the rivers to the Baltic ports. It has some large annual fairs, and is 611 miles from Petersburg. Long. 32. 39. E. Lat. 53. 6. N.

MIANA, a village of Persia, in Azerbijan. Here the celebrated traveller Thevenot died upon his return from Ispahan. It is 60 miles S. E. from Tabreez.

MIASSE, a considerable river of Asiatic Russia, which rises in the Ural Mountains, and, traversing the district of Kourgan, in the government of Tobolsk, falls into the Icette.

MIASMA, amongst physicians, a particular kind of effluvia, by which certain fevers, particularly intermittents, are produced.

MIAVA, a town of Hungary, in the circle of Neustadt, in the province of the Lower Danube. It stands upon the river Waag, and is a manufacturing place, producing large quantities of linen and woollen cloths, of blankets and quilts; there are also several distilleries and extensive tanneries. The inhabitants amount to 10,000 persons, who are chiefly of the Slavonian race.

MICA, a simple mineral substance, the common term for which is *Muscovy Glass*. See MINERALOGY.

MICAH, or *The Book of MICAH*, a canonical book of the Old Testament, written by the prophet Micah, who is the sixth of the twelve lesser prophets.

MICHAEL, MOUNT, formerly one of the most celebrated state-prisons of France. It is a rock situated in the middle of the Bay of Avranches, and is only accessible at low water. Nature has completely fortified one side, by its craggy and almost perpendicular descent, which renders it impracticable to ascend it by any address or courage. The other parts are surrounded by walls fenced with semilunar towers after the Gothic manner, but sufficiently strong, together with the advantage of its situation, to render it impregnable to any attack. At the foot of the mountain begins a street or town, which winds round its base to a considerable height. Above are chambers where state-prisoners are kept, and where there are other buildings intended for residence. On the summit is erected the abbey itself, occupying a prodigious space of ground, and of a strength and solidity equal to its enormous size; since it has for many centuries withstood all the injuries of the weather, to which it is so much exposed. In an apartment called the *Salle de Chevalerie*, the knights of St Michael used to meet in solemn convocation on important occasions. They were the defenders and guardians of this mountain and abbey, as those of the Temple, and of St John of Jerusalem, were of the holy sepulchre. The hall in which they met is very spacious, but rude and barbarous.

MICHAEL'S MOUNT, *St*, in the county of Cornwall, and in the corner of Mount's Bay, is a very high rock, only divided by the tide from the main land, so that it is land and island twice a-day. The town here was burned by the French in the reign of Henry VIII. At the bottom of this mount, in digging for tin, there have been found spear-heads, battle-axes, and swords, of brass, all wrapt up in linen. The county is contracted here into a sort of isthmus. Large trees have been driven in by the sea between this mount and Penzance.

MICHAELIS, JOHN DAVID, a celebrated biblical critic, and author of many esteemed works, was the eldest

son of Dr Christian Benedict Michaelis, professor in the university of Halle, in Lower Saxony, and was born at that place on the 27th of February 1717. His father devoted him at an early age to an academical life; and with that view he received the first part of his education in a celebrated Prussian seminary called the Orphan-house, at Glanche, in the neighbourhood of his native place. He commenced his academical career at Halle in 1733, and took his master's degree in the faculty of philosophy in 1739. In 1741 he made an excursion to this country, where his superior knowledge of the oriental languages, which was considerably increased by his indefatigable researches in the Bodleian Library at Oxford, introduced him to the acquaintance, and gained him the esteem, of our first literary characters, with several of whom, particularly Bishop Lowth, he afterwards corresponded for many years. On his return to Halle, after an absence of fifteen months, he began to read lectures on the historical books of the Old Testament, which he continued after his removal to Göttingen in 1745. In 1746 he was appointed professor extraordinary, and soon afterwards professor of philosophy, in that university. The next year he obtained the place of secretary to the Royal Society there, of which he was director in 1761, and he was soon afterwards made aulic counsellor by the court of Hanover. In 1764 his distinguished talents, and a publication relative to a journey to Arabia, which was undertaken by several literary men at the expense of the king of Denmark, in consequence of his application through Count Bernsdorf, procured him the honour of being chosen a corresponding, and afterwards a foreign, member of the Academy of Inscriptions at Paris, of which class the institution admitted only eight; and in the same year he became a member of the society of Haerlem. In 1775 Count Hopkin, who, eighteen years before, had prohibited the use of his writings at Upsal, when he was chancellor of that university, prevailed upon the king of Sweden to confer upon him the order of the Polar Star, as a national compensation. In 1786 he was raised to the distinguished rank of privy counsellor of justice by the court of Hanover; and in 1788 he received his last literary honour, by being unanimously elected a fellow of the Royal Society of London. His great critical knowledge of the Hebrew language, which he displayed in a new translation of the Bible, and in other works, raised him to a degree of eminence almost unknown before in Germany; and his indefatigable labours were only equalled by his desire of communicating the knowledge he had acquired to the numerous students of all countries who frequented his admirable lectures, which he continued to deliver, in half-yearly courses, on various parts of the sacred writings, and on the Hebrew, Arabic, and Syriac languages, to the last year of his life. He was forty-five years professor in the university of Göttingen, and during that long period he filled the chair with dignity, credit, and usefulness. He died on the 22d of October 1791, in the seventy-fourth year of his age.

MICHAELMAS, or *Feast of ST MICHAEL and all Angels*, a festival of the Christian church, observed on the 29th of September.

MICHEL ANGELO BUONAROTTI, the greatest master of the arts of design who has appeared since the days of Phidias, was born in the castle of Caprese, in Tuscany, on the 6th of March 1474. His father, Ludovico di Leonardo Buonarrotti Simone, was a descendant of the noble and illustrious family of the counts of Canossa, and allied to the imperial blood. This circumstance had nearly occasioned the world the loss of the great artist; for when the strong bias of his mind became apparent, which occurred at a very early age, his father and uncles discouraged his pursuits, and treated him with harshness, conceiving that their family would be de-

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Michel Angelo. graded should a scion of their race adopt the profession of artist. But objection, prejudice, and even persecution, proved useless when opposed to devoted attachment and irresistible genius. Michel Angelo received the rudiments of his education at Florence, the nursing-mother of the arts, and here he enjoyed ample facilities of gratifying his taste for drawing. Ludovico finding it hopeless to attempt to frustrate the intentions of nature, yielded at last to the advice of friends, and the wishes of his son, who was accordingly placed under Domenico Ghirlandaio, a distinguished professor of the arts of painting and design. The youth was articled to serve three years; but, contrary to custom, instead of paying, he received a premium, an indubitable proof of his great merits, even at the age of fourteen. The original document by which he was engaged bears date April 1488. His earliest effort in oils showed that he was born to grapple with difficulties from which other men shrink, whilst his success proved that he was also destined to overcome them. The subject was St Antony beaten by devils. In this little picture, besides the figure of the saint, there were crowded wild and grotesque forms and monsters, to which he was so intent upon giving an aspect of reality, that he painted no part without referring to some natural object. But painting did not engross the whole of his time and attention. The great patron of the arts at this period was Lorenzo de' Medici, who, for the purpose of elevating sculpture to a level with painting, opened a garden in Florence, which he amply supplied with antique statues, bas-reliefs, busts, and the like. Thither the youth of the city repaired to study the classic creations of antiquity; and it is scarcely necessary to say that it became the favourite haunt of Michel Angelo.

From copying the drawings and paintings of others, his attention was turned to the modelling of figures in clay, in imitation of the monuments of ancient art; and the transition from this, the initiatory step in sculpture, to the moulding of the marble into symmetrical forms, was natural, and speedily withdrew his mind from every other study. The vigilant and practised eye of Lorenzo soon discovered the genius of the youthful sculptor in the execution of a mask representing a laughing faun. His father was sent for, and requested to resign Michel to the care of the family; and this being complied with, apartments were allotted to him in the ducal palace. Here he received every indulgence and attention, being treated with parental affection, and allowed to pursue the bent of his genius, not only without interruption, but cheered and encouraged by the cordial approbation of his munificent patron. Amongst the works which he executed under these favourable auspices, was a bas-relief representing the battle of the Centaurs; on viewing which at a future period of his life, he lamented that he had not confined himself to a branch of art wherein he had so soon attained such excellence. This is the strongest evidence which could be produced of the rare merits of the sculpture; for artists almost uniformly speak disparagingly of their early efforts.

On the death of Lorenzo, which happened about two years after he had entered his service, Michel Angelo, with a heavy heart, returned to the paternal mansion. Nothing belonging to Lorenzo was inherited by his son Piero, except the territorial possessions of the family; and although the young artist continued to pursue his studies with unabated zeal, little patronage or encouragement was to be expected or obtained from a frivolous debauchee. The pusillanimity of this person soon distracted the councils of Florence; and Michel, to escape the storm which he saw impending over that city, retired to Bologna, but returned in about a year afterwards, when tranquillity had been restored. About this period there prevailed a sort of mania for the antique. Whilst the discoveries of antiquity created a new

era in art and literature, the importance of which can never be too highly estimated, many ignorant individuals, smitten with the enthusiasm of the time, betrayed their want of judgment by the indiscriminate manner in which they lavished their praise on these remains; and Michel Angelo resolved to take advantage of the popular excitement. He executed a Sleeping Cupid; and having stained the marble in such a way as to give it the appearance of a genuine antique, it was transmitted to a proper person in Rome, who, after burying it in his vineyard, dug it up, and then reported the discovery. The pardonable trick completely succeeded for a time, and the statue was bought by a cardinal for a considerable sum; but of this Michel Angelo received only a small portion. Such deceptions, however, seldom remain long concealed; the officious zeal of friends, or the vanity of authorship, usually brings about the exposure of a successful imposition. After the mask was laid aside, and the real artist became known, he received a flattering invitation to visit Rome. Thither he accordingly repaired, and whilst there he executed a statue of Bacchus, another of a Cupid, and a group of the Virgin with a dead Christ reclining on her knees, together with a cartoon representing St Francis receiving the *stigmata*.

The celebrated gonfaloniere, Pietro Soderini, well known as a patron of genius, having been elected to guard the peace and protect the liberties of Florence, Michel Angelo returned to that city. With the sanction of the new chief magistrate, he was allowed to appropriate to his use a huge block of marble, which had for many years lain neglected in Florence; and out of this he executed a gigantic statue of David, which gave great satisfaction. He also cast a figure in bronze, of the size of nature, and a group of David and Goliath; but, that his hand might not "lose its cunning" in the sister art, he painted a Holy Family. This picture is preserved in the Florence gallery; and it is the only painting in oil by Michel Angelo now remaining, the authenticity of which is not disputed. Having been commissioned to ornament the hall of the ducal palace with a cartoon, he chose for the subject an event connected with the war between the Florentines and Pisans. The work represents the Florentine soldiers, who, alarmed by an unexpected assault whilst bathing in the Arno, are getting out of the water with the utmost expedition, and preparing for action; and, although only outlined in charcoal, chalk, and the like, it was considered as the most extraordinary production which had appeared since the revival of the arts in Italy. In the mean time Julius II. having been raised to the pontifical throne, Michel Angelo was invited to the Vatican, whither he repaired without finishing the cartoon; but being disgusted with Rome, he returned to Florence, and completed the design. The painting of the picture itself, however, was never begun. Political events, and a second invitation from Julius II. again attracted him to the Eternal City, and he was employed by his holiness to construct a magnificent mausoleum, which, although immediately commenced, was interrupted during its progress, first on account of a misunderstanding between the artist and the pope, and afterwards from other causes. The artist repaired to Bologna, and political events having brought the pope to this city, a reconciliation took place. In a few days Julius II. ordered a colossal statue of himself to be executed in bronze, which Michel Angelo finished in sixteen months, and returned to Rome at the end of June 1508. He was, however, disappointed in his hopes of being allowed to proceed with his great architectural undertaking; for the pope had changed his mind, it is alleged through the jealousy of Bramante, and the artist was requested to decorate with pictures the ceiling and walls of the Sistine Chapel. But his primary disappointment was forgotten in his subsequent triumph. This stupendous work of genius excited the highest admiration,

Michel Angelo.

Michel
Angelo.

which contemporary opinion and the judgment of after ages have confirmed; yet, from its commencement till its conclusion, only eighteen or twenty months elapsed.

After the death of Julius II. in 1513, the papal throne was filled by Leo X., whose magnificent reign forms an era in the intellectual history of modern times. Yet, strange as the fact may appear, the life of Michel Angelo during his pontificate is nearly an entire blank. He was employed in extracting marble from a quarry which was wrought with difficulty, and in constructing a road over intricate swamps and through mountainous ridges, for the purpose of conveying it to the sea. Leo X. died in 1521, and under his successor Adrian VI., Michel Angelo employed himself upon the monument of Julius. The reign of Adrian was short, and on his death Clement VII. was raised to the papal throne. The confusion with which the civil affairs of Rome were soon overwhelmed, drove the artist to Florence, where he continued his architectural and other works for the chapel and library of S. Lorenzo, and executed a statue of Christ. His talents as an engineer were likewise put in requisition for the defence of the city. Before commencing the works, he visited Ferrara, then the best fortified town in Italy, and was received with the utmost courtesy by the Duke Alphonso, who showed him every part of the works, and at the same time requested a specimen of the artist's abilities either in sculpture or in painting. A picture of Jupiter and Leda was the result; but this great production is generally supposed to have been lost. Michel Angelo was enabled to complete the fortifications of Florence before the siege of the city commenced; and, as in the case of Syracuse, the genius of one individual for a considerable time proved more than a match for thousands of armed men and the mightiest engines of war. By treachery the city passed into the hands of the enemy; but the great artist, although he had shown the dexterity of Archimedes in frustrating the designs of the besiegers, did not share the fate of the great geometrician. The finishing of two monuments for the Medici family was the price of his liberty.

Tranquillity being restored to Italy, Buonarrotti returned to Rome; and although frequently interrupted, both by Clement VII. and by his successor Paul III., he at last completed the monument to Julius II. It consists of seven statues, amongst which is the celebrated one of Moses, a production evincing, in a higher degree than any of his other sculptures, that character of majesty and sublimity which more or less pervades them all. His next work was the painting of the Last Judgment in the Sistine Chapel, which was finished in 1541; and so great was the admiration excited by this mighty effort of genius, that many persons came from distant parts of Italy to see it. He subsequently painted the martyrdom of St Peter and the conversion of St Paul, which cost him great fatigue, as age was beginning to impair his physical energies. But that his intellectual powers still retained their pristine vigour, the church of St Peter's, the most splendid monument of his genius and success as an architect, affords ample evidence. This fabric was begun by Julius II. in 1506, and, being successively intrusted to Bramante and Antonio de San Gallo, by this transference from hand to hand it was in danger of becoming a huge incongruity. On the death of the last-named architect in 1546, Michel Angelo was appointed architect; and, notwithstanding the jarring and complexity of the original designs, he succeeded in simplifying and harmonizing the whole. The work proceeded for a time with considerable rapidity. But he was occasionally withdrawn from it to other things, such as the building of bridges, the superintendence of which might have been safely intrusted to some inferior person. During the latter years of his life the papal chair was filled by several pontiffs, some of whom forwarded, and others

retarded, his great undertaking, employing him in the construction of chapels and other buildings. Nor did he live to witness the completion of this splendid edifice, the greatest and most magnificent Christian temple on earth. He was carried off by a slow fever on the 17th of February 1563. His obsequies were celebrated as became the memory of so unrivalled a genius. Michel Angelo was of the middle stature, bony in his make, and rather spare, but broad over the shoulders. His complexion was good; his forehead was square, and somewhat projecting; his eyes were of a hazel colour, but rather small; and the general effect of his countenance was impaired by a blow which he had received in youth.

The character of Michel Angelo as an artist has already been delineated in this work by a masterly hand (see the article ARTS, FINE). Grandeur of conception is the quality which distinguishes his works from those of all other artists who have appeared in modern times. Whether he excelled most in painting, in sculpture, or in architecture, it would not be easy to determine. He has left the noblest specimens of human genius in each department of art. He is the Milton of artists. Things beyond the visible diurnal sphere were within the range of his imagination; and when he stoops to earth, he invests nature with an ideal grandeur and majesty. His boys are men, his men are a race of giants; his demons are the evil spirits of Dante and Milton made visible; and his angels are the offspring of the sky. The Sistine Chapel is allowed to be the most finished work of art in the world; and its perfection is owing chiefly to Michel Angelo's divine paintings. The whole wall behind the altar is covered by his picture of the Last Judgment; the vaulted ceiling represents the creation of the world, and around it are prophets and sibyls. In the sublime painting of the Last Judgment, terrible power is the predominating feature. The good and the bad, angels and devils, crowd the scene, and Christ is represented in the act of judging, or rather of condemning. His complete knowledge of anatomy, which he constantly studied, enabled him to represent in the most perfect manner the human figure in every possible attitude, and to express pain and despair through all their gradations. His other pictures exhibit the same daring sublimity of conception and power of execution. The church of St Peter's at Rome is the most splendid triumph of his architectural talents. His style in architecture is distinguished by grandeur and boldness; and, in his ornaments, the untamed character of his imagination is frequently apparent, in his preference of the uncommon to the simple and elegant. In sculpture, his statue of Moses is universally acknowledged to be the noblest monument of his genius, displaying, more than any other of his numerous works in this department of art, all the great qualities of his mind. Michel Angelo was likewise an author, and excelled both in verse and prose. His works have been printed in several collections; but they have also been published separately. (R. R. R.)

MICHELDEAN, a town of the county of Gloucester, in the hundred of St Breavell, 119 miles from London. It is on the western side of the Severn, in the forest of Dean, which abounds in mines of coal, and in iron-works, that have consumed much of the wood that formerly covered it. The town consists principally of one long street. The population amounted in 1821 to 556, and in 1831 to 601.

MICHIGAN, one of the United States of North America, which, until 1835, was denominated a territory. It is situated between 41. 38. 58. and 47. 29. of north latitude, and 82. 44. and 90. 40. of west longitude, being bounded on the north by Lake Superior and the Straits of Michilimackinac, on the south by Ohio and Indiana, on the west by a portion of Wisconsin and Lake Michigan, and on the east by Lakes Huron, St Clair, and Erie, and their

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Michigan. waters. The lower and most important portion may be described as a large triangle, with its base resting upon the states of Ohio and Indiana. It is two hundred and fifty miles in length from north to south, from one hundred and eighty to two hundred miles in breadth from east to west, and comprehends a superficies of about 36,000 square miles. The surface of this state is generally level, or gently undulating, there being no mountains, nor even elevations, with the exception of a strip of table-land, stretching north and south, and assuming towards the north the character of a ridge, but at the highest it is only three hundred feet above the level of the lakes. Notwithstanding the almost uniform flatness of the country, there is comparatively little swampy or wet land; at any rate, not so much as is found on the northern belt of the state of Ohio adjoining the lakes. The soil is a bed of alluvial earth from thirty to one hundred and fifty feet deep, resting upon limestone and argillaceous sandstone. Ferriferous sand rock, saliferous rock, and millstone grit, are found alternating on the surface, at various points in the middle and western parts of the peninsula. The general level of the interior, towards the sources of the rivers, is interspersed with lakes and morasses; and a considerable belt of land along the southern shore of Lake Michigan is sandy and sterile, being exposed to the bleak and desolating gales of the lake. But a great proportion of the land is fertile, and well adapted to the purposes of agriculture. The country generally is divided into nearly equal proportions of grass prairies, distinguished, according to their prevailing character, by the names of wet and dry; and broad and deep forests of trees, nearly similar to those of Kentucky, namely, black walnut, black cherry, honey locust, buck-eye, pawpaw, sugar-tree, mulberry, elm, ash, hawthorn, coffee-tree, and the grand yellow poplar, which indicates the richest soil. South of a line drawn due west from the southern extremity of Lake Huron, Michigan consists of open land, known by the name of *Oak Plains*. The soil is a loam, with varying proportions of clay. It becomes fertile by cultivation, and is good farm land. In the country bordering on the Kalamazoo and St Joseph Rivers, prairies of a black, rich, alluvial soil, and unusual productiveness, frequently occur. The northern part of the peninsula is less known, being occupied by Indians; but the land there is in many parts more elevated than that farther south, and is covered with the trees usually met with in those latitudes. Amongst the minerals found in this state may be mentioned bog iron ore, lead ore, gypsum, and bituminous coal, but none of them are present in great quantities. Peat is abundant in many parts. There is a plentiful supply of water everywhere; rivers with their tributaries, and small lakes and springs, being unusually numerous. The principal stream is Grand River, which flows into Lake Michigan. It rises in the south-east angle of the state, and interlocks at its sources, or in its course, with the waters of the Raisin (which derives its name from the number of vine-trees on its banks), the Black, the Mastigon, and the Sagana. Small boats reach its source, and, by means of this river and that of the Huron, periogues pass from Lake Michigan to Lake Erie. The St Joseph is a considerable stream, falling also into Lake Michigan; as do the Kikamezo, Barbue, Beauvaise, St Nicholas, Marguettes, and other rivers. On the other side of the peninsula are the Detroit, which is twenty-five miles in length, and above a mile in average breadth; the St Clair, which is forty miles in length and half a mile in average breadth; the St Mary's, which is fifty miles in length and three quarters of a mile in average breadth; and the Huron, Thunder, and Sagana, which are considerable rivers. Other streams there are in abundance, but not of such magnitude as to merit particular attention.

The peninsula of Michigan being surrounded upon all

sides, excepting the southern extremity, with water, the various lakes and straits require to be described. That lake which bears the name of the state is one of the five great lakes in the northern part of the United States. It is nearly three hundred miles in length, about sixty miles in breadth, and has an average depth of about nine hundred feet. The waters are clear and wholesome, and contain many kinds of fish. In the north-west part there are two large bays, called Noquet's and Green; and on the east side there are also two, called Sable and Grand Traverse. Lake Michigan is connected with Lake Huron by the Straits of Michilimackinac, a channel forty miles in length from east to west, and four miles in breadth at the narrowest part. Lake Huron is two hundred and eighty miles in length, about ninety miles in breadth, and has a medium depth of nine hundred feet. There are two large bays on this lake called Thunder and Sagana, the latter of which is about forty miles in length, by from eight to twelve in breadth. Lake Huron is connected with Lake St Clair by a strait of the same name, twenty-six miles in length, and having deep groves of beautiful white pine all along its banks. Lake St Clair is only twenty-four miles in length by forty in breadth, and about twenty feet in depth. It is connected with Lake Erie by the Strait of Detroit, which is twenty-four miles in length, narrow, and studded with islands, but navigable by large vessels. A rise and fall of water has been observed in some of these inland seas, particularly at certain points of Lakes Michigan and Huron; but the experiments instituted have failed to determine whether these are to be regarded as tides corresponding with the flux and reflux of the ocean. In the interior of this state there are great numbers of small lakes and ponds, from which the rivers chiefly derive their origin.

In consequence of the level nature of this region, and from its being nearly surrounded by a belt of noble lakes, the climate is milder and more temperate than might have been expected from its latitude. The southern parts are, of course, more so than the northern, which is subjected to a Canadian temperature. The transition from the cold of spring to the heat of summer is rapid; but the change from summer to winter proceeds by slow degrees. As generally characterising the climate, the spring may be termed wet and backward, with an average temperature of 50° of Fahrenheit; the summer dry, with a temperature of 80°; the autumn mild, with a temperature of from 60° to 65°; and the winter dry but cold, the temperature being only from 20° to 25° upon an average. The winter commences early in November, and does not terminate until the end of March. The climate throughout the whole state is considered as healthy. From the general fertility of the soil, the productions, as well natural as cultivated, are numerous. The wild rice or wild oats, which covers the marshes near the margins of the lakes and rivers, is a valuable grain of the former class. The great varieties of forest trees we have already noticed. Wheat, Indian corn, oats, barley, buck-wheat, potatoes, turnips, peas, apples, pears, plums, cherries, and peaches, are raised easily and in abundance; and no part of the United States is more abundantly supplied with fish, aquatic game, and wild fowls. The country is favourable to cultivated grasses, more so than the territory to the westward; and in all respects it is well adapted to farming operations. Possessing admirable facilities for commerce, Michigan enjoys considerable trade. A number of steam-boats are continually plying upon the lakes, bays, and rivers, by far the largest proportion of which belong to Detroit, the capital. No inland country, considering its comparatively recent settlement, possesses a greater trade. The value of the imports for the year ending 30th September 1833 was 63,876 dollars, and the value of the exports for the same year was 9054 dollars; the whole consisting of domestic produce.

Michigan. Detroit is the political capital, and the only place of any size in the state. It is situated upon the western bank of the river of the same name, eighteen miles from Lake Erie, and seven from Lake St Clair. It was settled as early as 1683 by the French from Canada, who penetrated these inland districts for the purpose of prosecuting the fur trade. Its site is an elevation of between twenty and thirty feet above the level of the river, and the plain upon which it stands is adorned with beautiful and romantic scenery. The plan of the town upon the river, and for twelve hundred feet backwards, is rectangular; behind this it is triangular. The streets are wide and airy, three of them running parallel to the river; and these again are crossed at right angles by six other streets. It contains above four hundred houses, some of which are built of stone. The public edifices are, a council-house, state-house, United States store, a Presbyterian church, a Roman Catholic chapel, and other buildings. Three roads, constructed by the general government, terminate in the centre of this town; the Chicago, leading to Illinois; the Sigana, leading to the head of Sigana Bay; and the fort Gratiot, to the foot of Lake Huron. A United States road, leading from Detroit to Ohio, has also been completed. Several wharfs project into the river, one of which is 140 feet long; and vessels of 400 tons burden can load and unload at its head. The population of this place in 1830 amounted to 2222, but it has since been greatly augmented. A strong and increasing tide of immigration has set in; and as its situation is favourable for a very extensive inland commerce, it must rapidly rise into a town of considerable importance. Hitherto its prosperity has depended principally on the precarious support afforded by the fur trade, the disbursement of public monies whilst it was a military post, and the liberal appropriations of government for public objects. But the settlement and cultivation of the surrounding country has advanced considerably, and the impulse and vitality which this has imparted to trade is already great. In 1834 it possessed thirteen steam-boats, one brig, thirty-three schooners, and thirty-five sloops, being an aggregate tonnage of four thousand nine hundred and thirteen. A considerable number of these vessels trade between Detroit and Ohio; others go regularly to Buffalo and other places. All along the banks of the Detroit River are numerous mansions, chiefly built by the French. They are embosomed in ancient and rich orchards, all having an appearance of comfort, and some of splendour and opulence.

Mackinac, or Michilimackinac, is a post-town and also a military post in this state. It is situated on an island of the same name, about nine miles in circumference, lying in the strait which connects Lakes Huron and Michigan. The town stands on the south-east side of the island, on a small cove, which is surrounded by a steep cliff one hundred and fifty feet in height. It consists of two streets running parallel with the lake, intersected by others at right angles, and contains a court-house, a jail, and several stores. It is much resorted to by fur traders, and during the summer months is visited by thousands of Indians on their way to Drummond's Island. On a cliff above the town is the fort, which is remarkably strong, indeed almost impregnable. The population of the island may be about 1000. There are a number of other islands in Lake Michigan, the largest of which, called Manitou, is six miles in length and four in breadth. Fort Gratiot is a military post on St Clair River, and defends the entrance into Lake Huron. The Sault de St Marie is of importance as a military and trading post, being at the head of ship navigation on the great lakes, and the grand thoroughfare of Indian communication for the upper countries as far as the arctic circle, all the fur trade of the north-west necessarily

passing through it. It is a tract of land four miles square, commencing at the Sault, and extending two miles up and two down, with a depth of four miles.

Table showing the number of Counties into which Michigan is divided, with their Extent, Capitals, and Population.

Counties.	Square Miles.	Population, 1837.	Capitals.	Population, 1838.
Allegan	840	1,469	Allegan	1,200
Arenac	545			
Barry	576	512		
Berrien	578	4,863	St Joseph	1,300
Branch	528	4,016	Branch	
Cass	528	5,296	Cassopolis	
Calhoun	720	7,660	Marshall	1,000
Chippeway	7,200	366	Sault St Mary	800
Clinton	576	529		
Eaton	576	913	Bellevue	400
Genesee	504	2,754	Flint	1,200
Gladwin	576			
Gratiot	576			
Hillsdale	576	4,729	Jonesville	
Ionia	576	1,028	Ionia	
Ingham	560	822		
Isabella	576			
Jackson	720	8,693	Jackson	
Kalamazoo	576	6,367	Kalamazoo	
Kent	576	2,022	Grand Rapids	1,000
Lapeer	828	2,602	Lapeer	
Lenawee	735	14,540	Adrian	1,200
Livingston	576	5,029	Howell	
Mackinac	27,684	664	Mackinac	
Macomb	458	8,892	Mt. Clemens	
Midland	680			
Monroe	532	10,611	Monroe	2,795
Montcalm	576			
Oakland	900	20,163	Pontiac	1,000
Oceana	834			
Ottawa	794	628		
Saginaw	1,021	920	Saginaw	400
Sanilac	2,460			
Shiawassee	544	1,184	Corunna	
St Clair	935	3,673	Palmer	
St Joseph	528	6,337	Centreville	
Van Buren	633	1,262		
Washtenaw	720	21,817	Ann Arbor	2,000
Wayne	600	23,400	DETROIT	9,278
Total	60,520	175,169		

The white population is given in the above. The coloured population is stated at 379; Indians taxed, 27; two townships in the counties of Lapeer and Lenawee not returned, computed to contain 425 inhabitants. Population in 1810, 4528; in 1820, 9048; in 1830, 32,538; in 1834, 87,278, in 1837, 175,169.

The Indians who reside in this state are chiefly the Ottawas, Miamies, Pottawattomies, Chippeways, and Wyandots. They have ceded the greater part of their native soil to the United States; but they still retain some fine tracts of country, and have many reservations and villages even amongst the settlements. The Ottawas and Chippeways are hunters and trappers. The former are the most agricultural in their habits; and a band of this tribe have a flourishing settlement at L'Arbre Croche, on the western coast of Lake Huron. Some of the Indians have made considerable advances in cultivation and the arts of civilized life. Most of the converts to Christianity are Roman Catholics; but the Protestants have within these few years established missionary stations and schools amongst them. Their numbers are gradually diminishing, and the whole may not exceed 8000. The borders of St Clair River and Lake, Rivers Detroit, Raisin, Clinton, and Plaisance Bay at the mouth of the Raisin, are settled by French inhabitants. They occupy a belt of land upon the borders of these streams, three miles broad. They are civil, honest, unobtrusive, and industrious, with little education, and essentially deficient in enterprise.

This state began to be regularly settled about the beginning of the last century. Under the French the government was arbitrary, uniting the civil and military authority in the power of a "commandant." In the year 1763 it passed into the hands of the British, along with other possessions in this quarter, which had been wrested from the crown of France. By the treaty of Paris of 1783, the country was transferred to the United States; and although the British government held possession of the military posts until 1796, it ceased to exercise criminal jurisdiction over it from that period. Subsequently it was

Michigan. erected into a district territorial government. Upon the breaking out of the last war with America, this state became the theatre of part of the military operations. Mackinack was captured by the British, and Chicago surrendered to the savages. Soon afterwards the Americans made an inglorious surrender of Detroit, of which Britain held possession for a year. But the disastrous affair on Lake Erie, together with the subsequent defeat of the British on land, changed the current of success, and Michigan was again amalgamated with the United States. For many years it continued to be only what is called a territory, sending a delegate to congress, who was elected biennially, and might debate in the great council of the nation, but could not vote on any question. On the 11th of May 1835 a constitution was formed by a convention which met at Detroit, with a view to the erection of Michigan into a free and independent state. This being submitted to the people for ratification or rejection in the October following, was approved of, and forwarded to congress, which, towards the close of the session of 1836, passed an act admitting Michigan into the Union as a state. The following are some of the principal features of the constitution, taken from the American Almanac for 1836.

The powers of the government are divided into three distinct departments; the legislative, executive, and judicial. The legislative power is vested in a senate and house of representatives. The representatives are chosen annually, and their number cannot be less than forty-eight, or greater than a hundred. The senators are chosen for two years, one half of them every year, and they consist as nearly as possible of one third of the number of the representatives. An enumeration of the inhabitants is to be made in 1837 and 1845, and every ten years after the latter period; and after every enumeration so made, and also after each enumeration made by order of the United States, the number of senators and representatives is to be apportioned anew amongst the several counties, according to the number of white inhabitants. The legislature meets on the first Monday in January every year. The executive power is vested in a governor, who holds his office during two years, and a lieutenant-governor, who holds his office for the same period. The governor, lieutenant-governor, and members of the legislature, are chosen at the same time.

The judicial power is vested in one supreme court, and in such other courts as the legislature may from time to time establish. The judges of the supreme court are appointed by the governor, with the advice and consent of the senate, for the term of seven years. Judges of all county courts, associate judges of circuit courts, and judges of probate, are elected by the people, for the term of fourteen years. Each township is authorized to elect four justices of the peace, who hold their offices for four years.

In all elections every white male citizen above the age of twenty-one years, having resided six months immediately preceding any election, is entitled to vote at such election. Slavery, lotteries, and the sale of lottery tickets, are prohibited. The seat of government is at Detroit, or such other place or places as may be prescribed by law, until the year 1847, when it is to be permanently fixed by the legislature. The governor has power to nominate, with the advice and consent of the legislature, a superintendent of public instruction, who shall hold his office for two years, and whose duties are prescribed by law. The legislature is required to encourage, by all suitable means, the promotion of intellectual, scientific, and agricultural improvement. The proceeds of all lands which have been or may be granted by the Union to this state for the support of schools, and which shall hereafter be sold or disposed of, are to remain a perpetual fund, the interest of which, together with the rent of all such unsold lands, is to be inviolably appropriated to the support of schools through-

out this state. The legislature is to provide for a system of common schools, by which a school may be kept up and supported in each district at least three months in the year; and any district neglecting to do so, may be deprived of its proportion of the interest of the public fund.

In the preceding part of this article, Michigan properly so called is described. In the table in page 8 are given the statistics for the whole state, including that large tract of country, estimated at 24,000 square miles, lying west of Lake Michigan. This region is bounded on the east by Lake Michigan, on the north by Lake Superior and the chain of small lakes connecting that inland sea with the heads of the Mississippi, and on the west and north-west by the Upper Mississippi. It has not been thoroughly explored; but, judging of the whole from those portions which have been examined, it is likely to become of great interest and importance as its natural resources are developed. The district included between the Fox and Wisconsin Rivers is particularly inviting. The soil is a rich black alluvial mould, irrigated by innumerable streams of water, unbroken by mountain ridges, and in all respects admirably adapted for agriculture. From its northern boundary south to the Milwaukee and the heads of Rock River, it is covered with a dense forest, which, as traced farther down to the southern head of Lake Michigan, opens into fertile and extensive prairies. It has been remarked as a geological characteristic, that the pebbles which are usually found upon the surface of these prairies, and to a depth of two or three feet downwards, are entirely wanting. Clay constitutes the succeeding stratum. More than 36,000,000 pounds of lead were yielded by the mining district in this region from the autumn of 1824 to that of 1829. Strong indications of the presence of copper appear on the southern shore of Lake Superior. By the treaty of Prairie du Chien, which was entered into in 1829, the United States purchased from several Indian tribes a tract of about six millions of acres of land, of which between two and three millions are supposed to be within the limits of the territory. About one hundred and thirty-two thousand acres in the vicinity of Green Bay have likewise been ceded. The former cession comprehends nearly all the mining district of the Upper Mississippi, and is occupied by various Indian tribes. The white population, which is confined chiefly to Green Bay, is estimated at ten thousand. Military posts are established at Green Bay, Prairie du Chien, Fort Snelling on the river St Peters, and Fort Winnebago at the portage of the Fox and Wisconsin Rivers. Settlements more or less extensive have been formed at Green Bay, Pembino on Red River, Lake Winnepeg, Prairie du Chien, the Mississippi, and the lead mine bordering on the latter river and the Wisconsin. (R. R. R.)

MICKLE, WILLIAM JULIUS, the translator of the *Lucretius*, was the son of Mr Alexander Mickle, a Scottish clergyman, who had formerly been a dissenting minister in London, an assistant to Dr Watts, and one of the translators of Bayle's Dictionary. He was born in London about the year 1735, and educated by his father, after whose death he came to Edinburgh to reside with his uncle, who was a brewer there, and who admitted him into a share of his business; but not being qualified to succeed in this line, he went to London about the time of the conclusion of the war which began in 1755, with a view to procure a commission in the marine service. In this he was disappointed; but he introduced himself to the first Lord Lyttelton, to whom he sent one of his poems. From his lordship, however, he received no other favour than that of being admitted to several interviews, and encouraged to persevere in his poetical plans.

From the time of Mr Mickle's arrival in London till the year 1765, it is not known how he employed his time, although it is probable that he was occupied in some branch

Micro-
meter.

of the printing business ; and in that year he engaged himself as corrector to the Clarendon press. From this time till 1770, he published several small pieces in prose and verse, which brought him into some notice ; and he was likewise a frequent writer in the *Whitehall Evening Post*. When not more than seventeen years of age, he had read Gas-tara's translation of the *Lusiad* of Camoens into French, and then projected the design of giving an English version of that poem. This, however, he was prevented from executing by various avocations till the year 1771, when he published the first book as a specimen ; and having prepared himself by acquiring some knowledge of the Portuguese language, he determined to apply himself entirely to the task of translation. With this view he quitted his residence at Oxford, and went to a farm-house at Forest Hill, where he pursued his design with unremitting assiduity till the year 1775, when the work was completed. During the time that Mr Mickle was engaged in this work, he subsisted entirely by his employment as corrector of the press ; and on his quitting that employment he had only the subscriptions which he received for his translation to support him. But notwithstanding these difficulties, he adhered steadily to the plan he laid down, and completed his task in about five years.

When his work had been finished, Mr Mickle applied to a person of high rank, with whom his family had been connected, for permission to dedicate it to him. The permission sought was granted, and his patron honoured him with a very polite letter ; but after receiving a copy, the latter did not think proper to take any notice of the author. The applause with which the work was received, however, soon banished from the author's mind the disagreeable sensations which had been occasioned by the contemptuous neglect of his patron, as well as some severe criticisms which

had been circulated concerning it. A second edition was prepared in 1778 ; and whilst he was meditating a publication of all his poems, he was appointed secretary to Commodore Johnstone, who had obtained the command of the *Romney*. In November 1779 he arrived at Lisbon, and was appointed by his patron joint agent for the prizes which were taken.

In June 1782 Mr Mickle married Miss Tomkins, daughter of the person with whom he had resided at Forest Hill whilst engaged in translating the *Lusiad*. Having received some fortune with this lady, and made a little money himself when in the service of Commodore Johnstone, he now enjoyed a comfortable independence. He afterwards fixed his residence at Wheatley, in Oxfordshire, where he died after a short illness, on the 25th of October 1788, leaving a son behind him. His poetry possesses considerable beauty, variety, and harmony of numbers. His life was without reproach ; his foibles were few and inoffensive, his virtues many, and his genius respectable.

MICONE, an island of the Archipelago, in the Turkish province of Andros, which, with the small islands which surround it, contains forty-six square miles, and about 6000 inhabitants, living in one town of the same name, and in many detached rural hamlets. Although the soil is not good, and there is a scarcity of water, yet much wine and some corn, besides olives and figs, are produced. A great number of seamen are educated in the island. There are very few Turks, except the officers of government. Long. 25. 59. E. Lat. 37. 30. N.

MICROCOSM, a Greek term signifying a *little world*, and used by some for *man*, who is supposed to be an epitome of the universe or great world.

MICROGRAPHY, the description of objects viewed with the assistance of a microscope. See MICROSCOPIC OBJECTS.

Micōne
||
Micro-
meter.

MICROMETER.

MICROMETER, from *μικρος*, *small*, and *μετρον*, *a measure*, is the name of an instrument generally applied to telescopes and microscopes, for measuring small angular distances within the field of the former, or the size of small objects within that of the latter.

Previously to the invention of the telescope, astronomers experienced great difficulty in measuring small angles in the heavens ; but we may safely infer from the observations of Hipparchus, that he had succeeded, either by the actual division of his instruments, or by estimation, in determining celestial arcs to *one third* of a degree.

When the telescope was applied by Galileo, and our countryman Harriot, to the examination of the solar spots, it does not appear that they executed their drawings from any other than estimated measures. This indeed seems quite certain in the case of Harriot, whose original sketches we have had an opportunity of inspecting. The elaborate solar observations of Scheiner made in 1611, with a telescope on a polar axis, and published in 1630 in his *Rosa Ursina*, though minutely laid down, and performed with great care, were certainly made without any instrument for subdividing the field of view.

Gascoigne. As telescopic observations, however, multiplied, astronomers felt the necessity of having something more accurate than their eye for ascertaining minute distances in the heavens ; and there can be no doubt that a micrometer was invented by our countryman Mr Gascoigne, previous to 1640, not long after the publication of the *Rosa Ursina*. According to the description of it which he addressed in

a letter to Mr Oughtred, and to the account of one of Gascoigne's own instruments which Dr Hooke examined, its construction is as follows :—A small cylinder, stretching across the eye-tube of the telescope, is cut into a fine screw throughout one third of its length, the other two thirds being formed into a coarser screw, with threads at twice the distance. This compound screw is confined at both ends to its place, the fine part of it passing through a female screw in one bar, and the coarse part through a female screw in another bar, these two bars being grooved into each other, as in a sliding rule. Hence, if a nicely ground edge is fixed to one bar, and another to the other bar, so that these edges are accurately parallel, a motion of the screw round its axis will separate these two edges, and each edge will move with a different velocity. The parts of a revolution are measured by an index and divided face, at the coarse end of the screw, while the number of whole revolutions is measured by a graduated bar moved by the coarse screw. The fine screw serves the purpose of keeping the middle part of this variable field (or the opening between the edges) in the axis or line of collimation of the telescope ; for while the coarse screw moves the edge which it carries from the other edge considered as fixed, the fine screw moves both the edges, and indeed the whole frame, in an opposite direction, with one half of the velocity, an effect which is produced by fixing its bar to the tube of the telescope.¹ As Mr Gascoigne fell in the civil wars, near York, in 1644, before he had given any full account of his invention, and its application to as-

¹ See Phil. Trans. No. 29, p. 540, Nov. 1667 ; Lowthorp's Abridgment, vol. i. p. 226 ; and Costard's History of Astronomy.

Introduction. tronomy, we are indebted to Mr Richard Townley, into whose hands one of the instruments fell, for the preservation of so valuable a relic. Mr Townley informs us that Mr Gascoigne had made use of his micrometer for some years before the civil wars, and had measured distances on the earth, determined the diameters of the planets, and endeavoured to find the moon's distance from two observations of her horizontal and meridional diameters. Mr Townley's instrument was of the size and weight of "an ordinary pocket watch." It marked 40,000 divisions in a foot, $2\frac{1}{2}$ divisions corresponding to a second of space. Mr Townley had it improved by a common watchmaker. Flamsteed was presented with one of the instruments in 1670, by Sir Jonas Moore; but though he left three guineas with Mr Collins to get proper glasses made for it, he could not procure them till autumn 1671, when he began his observations with it at Derby, and continued them with it in 1671, 1672, 1673, and 1674.¹ He informs us that Townley's improvement consisted in substituting one screw for two. He mentions also that Gascoigne had, in August 1640, measured with his micrometer the diameters of the sun and moon, and the relative distances of the stars in the Pleiades.

Hooke. Dr Hooke made an important improvement in this micrometer, by substituting parallel *hairs* for the parallel edges of the brass plates;² and Dr Pearson conjectures that he had adopted this construction in his zenith sector, by which he proposed, in his dispute with Hevelius, to measure *single seconds*.

Malvasia. It would appear, from the Ephemerides of the Marquis of Malvasia, published in the year 1662, that he had measured the distances of stars, and the diameters of the planets, and projected the lunar spots, by means of a *reticle* of silver wire fixed in the focus of the eye-glass of his telescope. In order to determine the distances of the wires which composed this network, he turned it round till a star moved along one of the wires, and having counted the number of seconds which the star took to pass over the different distances between the wires, he obtained a very accurate scale for all micrometrical purposes.

Auzout. About the year 1666, MM. Auzout and Picard, unacquainted with what had been done by Gascoigne, published an account of a micrometer.³ Auzout's micrometer is said to have divided a foot into 24,000 or 30,000 parts. It resembled the Marquis of Malvasia's, with this difference, that the divisions were measured by a screw, and he sometimes employed fibres of silk in place of silver wires.

Huygens. The celebrated Christian Huygens was also an early inventor of micrometrical methods; and the subject was prosecuted with great diligence and success by Cassini, Röemer, Bradley, Savary, Bouguer, Dollond, Maskelyne, Ramsden, Sir W. Herschel, Troughton, Wollaston, Arago, Fraunhofer, and Amici.

In giving an account of the inventions and methods of these various authors, we shall adopt the following arrangement:—

1. Description of wire-micrometers in which the wires are moved by one or more screws.
2. Description of wire-micrometers in which the angular distance of the wires is varied optically, by changing the magnifying power of the telescope.
3. Description of double-image micrometers in which two singly refracting lenses, semi-lenses, or prisms, are separated by screws.
4. Description of double-image micrometers in which the two images formed by two singly refracting lenses, semi-lenses, or prisms, are separated optically.

5. Description of double-image micrometers in which the two images are formed by double refraction.
6. Description of position-micrometers.
7. Description of the lamp-micrometer, and the lucid disc micrometer.
8. Description of fixed micrometers with an invariable scale.
9. Description of micrometers for microscopes.

CHAP. I.—DESCRIPTION OF WIRE-MICROMETERS IN WHICH THE WIRES ARE MOVED BY MEANS OF ONE OR MORE SCREWS.

The micrometer of Gascoigne, when furnished with *Trough-hairs*, as suggested by Dr Hooke, embodies the principle of the best and most recent micrometers. Instruments of this construction have been made by all our eminent opticians; but we have no hesitation in saying, that the micrometer constructed by the late celebrated artist Mr Troughton combines all the ingenuity which has been displayed in this delicate and useful apparatus. This eye-piece, and micrometer attached to it, are shown in Plate CCCLVII. fig. 1, 2, and 3, where fig. 1 is a horizontal section in the direction of the axis of the telescope. The eye-piece AB consists of two plano-convex lenses A, B, of nearly the same focal length, and the two convex sides facing each other. They are placed at a distance less than the focal length of A, so that the wires of the micrometer, which must be distinctly seen, are beyond B. This arrangement gives a *flat field*, and prevents any distortion of the object. This eye-piece slides into the tube CD, which screws into the brass ring EF, through two openings, in which the oblong frame MW passes. A brass circle GH, fixed to the telescope by the screw I, has rack-teeth on its circumference, that receive the teeth of an endless screw W, which, being fixed by the arms XX to the oblong box MN, gives the latter and the eye-piece a motion of rotation round the axis of the telescope; and an index upon this box points out on the graduated circle upon GH, fig. 3, the angular motion of the eye-piece. The micrometer properly so called is shown in fig. 2, where K, L are two forks, each connected with a screw O and P, turned by the milled heads M and N. These forks are so fitted as to have no lateral shake. Two pins Q, R, with spiral springs coiled round them, pass loosely through holes in the forks K, L, so that when the forks are pressed by their screws towards Q and R, the spiral springs resist them, and consequently push them back when the screws are turned in the opposite direction.

Two fine hairs, or wires, or spiders' lines, S, T, are stretched across the forks, the one being fixed to the inner fork K, and the other to the outer fork L, so as to be perfectly parallel, and not to come in contact when they pass or eclipse one another, in which case they will appear as one line. A wire ST is stretched across the centre of the field, perpendicular to the parallel wires.

The most difficult part of this instrument in the execution, as well as the most important, is the screw or screws which move the forks. The threads must not only be at the same distance, but have their inclination equal all round. In the screw used by Troughton, there are about 103.6 threads in an inch. On the right hand of the line ST, fig. 2, is seen a scale, which indicates a complete revolution of either screw, the small round hole being the zero. This hole is bisected when the two lines appear as one.

In using this instrument, we separate the wires by their respective screws, till the object to be measured is exactly

¹ See Mr Baily's Account of the Reverend John Flamsteed, 1835, p. 24, 29, &c.

² Phil. Trans. No. 21, p. 373, January 1666.

³ Hooke's Posthumous Works, p. 497-8.

Wire-Mi- included between them. The number of revolutions and crometers. parts of a revolution necessary to bring the two wires into the position of zero, will then be a measure of the angle required, provided the value of a revolution has been previously ascertained with accuracy.

Methods of finding the value of a revolution of the screw.

The easiest method of ascertaining the value of a revolution of the screw, according to the late Dr Pearson, who devoted much attention to this subject, is to ascertain how many revolutions and parts of one measure exactly the sun's vertical diameter in summer, when his altitude is such that the refraction of both limbs is almost the same. The sun's diameter in seconds being divided by that number, the quotient will be the value of a single revolution, the sun's diameter having been corrected by the difference between the refraction of his two limbs. The ordinary method of ascertaining the value of a revolution is, to observe accurately the time taken by an equatorial star, or a star of known declination reduced to the equator, to pass over the space between the wires when at a distance, and to convert this time into degrees, at the rate of 15° per hour. The number of degrees, minutes, and seconds, divided by the revolutions and parts of a revolution which are necessary to bring both wires into zero, will give the value of one revolution of the screw. The same thing may be done by measuring a base with great accuracy, and observing the space comprehended between the wires at that distance. The angular magnitude of this space, divided by the number of revolutions of the screws which bring the wires to zero, will be the value of each.

New method.

A most elegant and accurate method has been recently employed, we believe by Professor Gauss of Göttingen, for measuring the value of the revolutions of micrometer screws. He employs for this purpose a standard telescope, with a micrometer the value of whose scale has been accurately determined. Since the wires of a telescope-micrometer adjusted to distinct vision of the stars or planets are accurately in the focus of parallel rays falling on the object-glass, it follows, that rays issuing from the wires and falling on the inside of the object-glass, will emerge from it perfectly parallel. Now, if we place the object-glass of the standard telescope close or near to that of the first telescope, the parallel rays formed by those issuing from its wires will be refracted to the focus of the standard telescope, and a distinct image of the wires will be there formed. The observer, therefore, when he looks into the standard telescope, will see distinctly the wires of the first telescope, and, by means of his micrometer, he will be able to measure exactly the angular distance of these wires, at whatever distance they happen to be placed. This angular distance divided by the revolutions and parts of a revolution which are necessary to bring the wires of the first telescope to the zero of their scale, will give the value of one revolution of the screw, or of one unit of the scale on the right hand of the long wire ST, fig. 2.

Fibres for micrometers.

The most essential parts of a micrometer are the parallel fibres, which require not only to be extremely fine, but of an uniform diameter throughout. Gascoigne, as we have seen, employed the edges of brass plates, Dr Hooke hairs, and subsequent astronomers wires and fibres of silk. Fontana, in 1775, recommended the spider's line as a substitute for wires, and he is said (we think erroneously) to have obtained them so fine as the 8000th part of a line. Mr Troughton had the merit of introducing the spider's line, which he found to be so fine, opaque, and elastic, as to answer all the purposes of practical astronomy. This distinguished artist, however, informed the writer of this article, that it was only the stretcher, or the long line which sustains the web, which possesses these useful properties. Sir David Brewster has employed the fibres of spun glass, which are bisected longitudinally with a fine transparent line about the $\frac{1}{3000}$ th of an inch in diameter. This central

line increases with the diameter of the fibre, and diminishes with the refractive power of the glass. In cases of emergency, the fibres of melted sealing-wax may be advantageously employed, or, as recommended by Professor Wallace, the fibres of asbestos. We have found crystals of *mesolite* so minute and regular as to be well adapted for the same purpose.

The art of forming silver wire of extreme minuteness has been perfected by Dr Wollaston. Having placed a small platinum wire in the axis of a cylindrical mould, he poured melted silver into the mould, so that the platinum wire formed the axis of the silver cylinder. The silver was now drawn out in the usual way, till its diameter was about the 300th of an inch, so that if the platinum wire was at first $\frac{1}{10}$ th of the diameter of the silver cylinder, it will now be reduced to the 3000th part of an inch. The silver wire is now bent into the form of the letter U, and a hook being made at each of its ends, it is suspended by a gold wire in hot nitric acid. The silver is speedily dissolved by the acid, excepting at its ends, and the fine platinum wire which formed its axis remains untouched. In this way Dr Wollaston succeeded in forming wire $\frac{1}{4000}$ th, $\frac{1}{5000}$ th, and even $\frac{1}{18000}$ th of an inch in diameter. When the fibres are prepared, their ends are placed in parallel scratches or grooves drawn on the forks, or, in other cases, on the diaphragm or field bar, and fixed by a layer of bees' wax or varnish, or, what is more secure, by pinching them with a small screw-nail near their extremities. For a great deal of valuable practical information respecting the construction and use of the wire-micrometer, the reader is referred to the late Dr Pearson's *Introduction to Practical Astronomy* (vol. ii. p. 99, 110, 115, &c.), where valuable tables will be found for facilitating the application of the micrometer, both to celestial and terrestrial purposes. See also Sir John Herschel and Sir James South's *Observations of 380 Double and Triple Stars* (p. 22, 23), containing tables of the values of Troughton's screws.

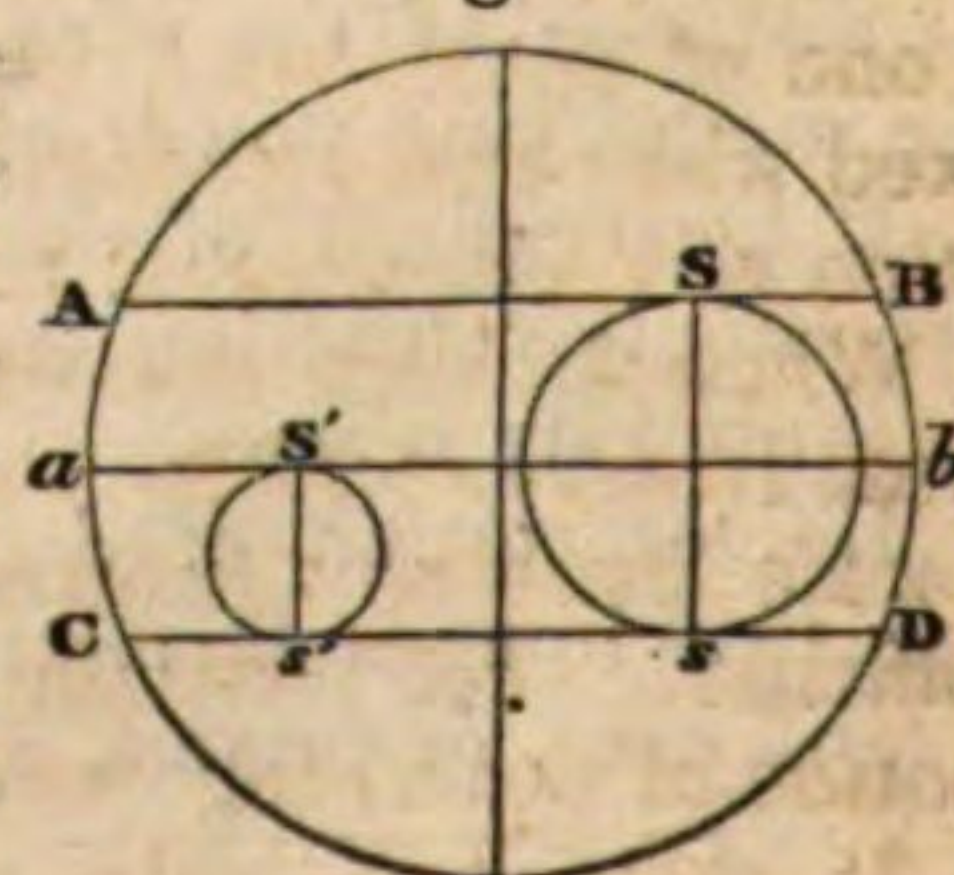
CHAP. II.—DESCRIPTION OF WIRE-MICROMETERS IN WHICH THE ANGULAR DISTANCE OF THE WIRES IS VARIED OPTICALLY BY CHANGING THE MAGNIFYING POWER OF THE TELESCOPE.

MM. Röemer and De la Hire first conceived the idea of varying the angular magnitude of the meshes of a net of silver wire fixed in the focus of the eye-glass of a telescope, for the purpose of measuring the digits of eclipses. This was done by a second lens moving between the wires and the object-glass. The late Mr Watt informed the writer of this article that he had used a similar principle, but had never published any account of it.

The plan of opening and shutting a pair of parallel wires optically instead of mechanically, and of using it as a general principle in micrometers, was first adopted by Sir David Brewster, and has been applied to a variety of methods of varying the magnifying power of the telescope.

The general principle will be readily understood from the annexed diagram, where AB, CD are two wires or lines of any kind permanently fixed in the focus of the eye-glass of a telescope. If the sun *S's* is in contact with the lower wire CD, it is obvious, that if we increase the magnifying power of the telescope by any optical means anterior to the wires, we may magnify or expand the sun's disc *S's*, till it becomes *Ss*, when its north or upper limb will exactly touch the upper wire AB. Now if the sun's diameter happens to be 31'

Fig. 1.

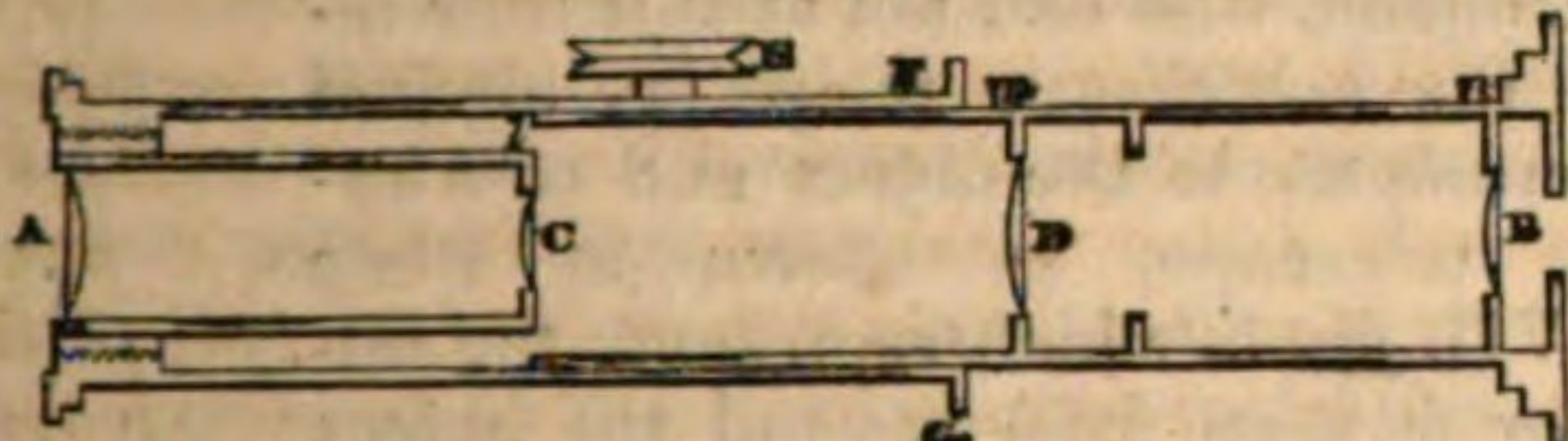


Wire-Mi- when its disc Ss just fills the space between the wires
crometers. AB, CD , the distance of the wires must have been $62'$
when, as at $S's$, it fills only half that space. Hence the
wires have been moved optically, so to speak, and have
subtended all angles between $31'$ and $62'$.

The methods of varying the magnifying power of the telescope used by Sir David Brewster, consist, 1, in varying the distance of the two parts of the achromatic eye-piece; and, 2, by varying the focal length of the principal object-glass by means of another object-glass, either convex or concave, moving between it and its principal focus.

The first of these methods is shown in fig. 2, where AB

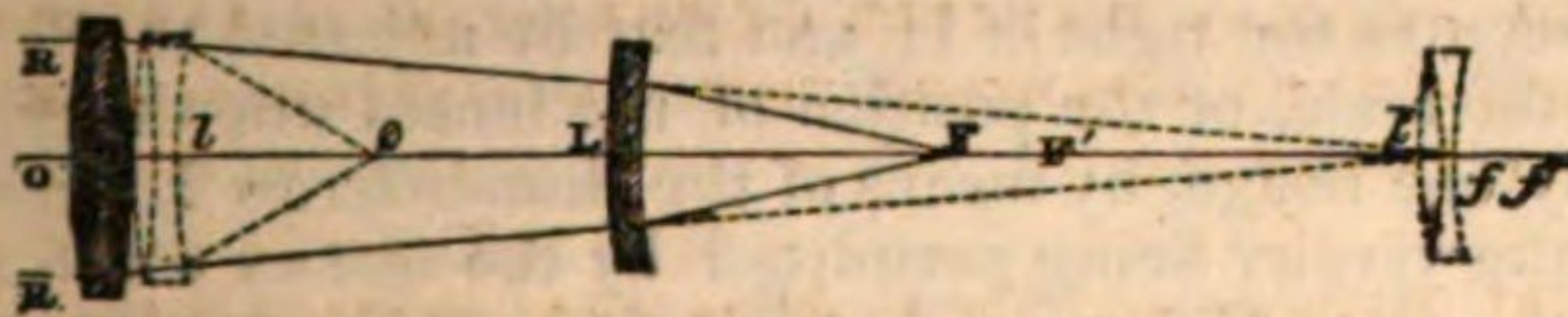
Fig. 2.



is the eye-piece with its four lenses, A, C, D, B , in their natural position. The part AFG , with the two lenses A, C , is fixed to the telescope, and a space is left between the tube AC and the outer tube AFG , to allow the moveable part DB of the eye-piece to get sufficiently near the lens C . The tube DB is moved out and in by a rack and pinion E . A scale is formed on the upper surface mn , and subdivided in the usual manner with a lens and vernier, which it is unnecessary to represent in the figure. The value of the divisions of the scale are determined by direct experiment. A motion of DB through a space of four inches will, generally speaking, double the magnifying power of the telescope.

The best method, however, of varying the magnifying power of the telescope is the second, which is shown in fig. 3, where O is the object-glass, f its principal focus, and

Fig. 3.



L the second lens, which is moveable between O and f . Parallel rays RR , after being refracted by O , so that they would converge to f , are intercepted by L , which converges them to F , the focus of the combined lenses. The effect of the lens L is therefore to diminish the focal length of the object-glass, and consequently the magnifying power of the telescope, which will obviously be a *minimum* when the lens L is at l , and a *maximum* when it is at l' . The angle subtended by a pair of fixed wires will suffer an opposite change to the magnifying power, being a maximum when the lens L is at l , and a minimum when it is at l' . Hence the scale for measuring the variable angle of these wires may always be equal to the *focal length* of the object-glass O ; and the inventor of the instrument has shown, both by theory and by experiment, that the scale is one of equal parts, the variations in the angle of the fixed wires being proportional to the variations in the position of the moveable lens.

When we wish to measure angles that do not suffer a great change, such as the diameters of the sun and moon, a scale less than the focal length of the object-glass will be sufficient. For example, if we take a lens L , which by a motion of ten inches varies the magnifying power from 40 to 35, then, if the angle of the wires is $29'$ when the lens L is at l , it will be $33' 9''$ when the lens is ten inches from l , or the magnifying power 35. We have, therefore, a

scale of *ten* inches to measure a change of angle of $4' 9''$, Wire-Mi- so that every tenth of an inch will correspond to $3'' 3$, and crometers. every 100th of an inch to $\frac{1}{3}$ d of a second. Such a micrometer will serve to measure the diameters of the sun and moon at their various distances from the earth.

If we wish to measure the distances of some double stars, or the diameters of some of the smaller planets, with a telescope whose magnifying power varies from 300 to 240, by the motion of a lens over *ten inches*, place the parallel wires at a distance of $40''$, which will be increased to $50''$ by the motion of the lens. Hence we have a scale of *ten inches* to measure *ten seconds*, or the *tenth* of an inch to measure *one second*, or the 100th of an inch to measure $\frac{1}{10}$ th of a second.

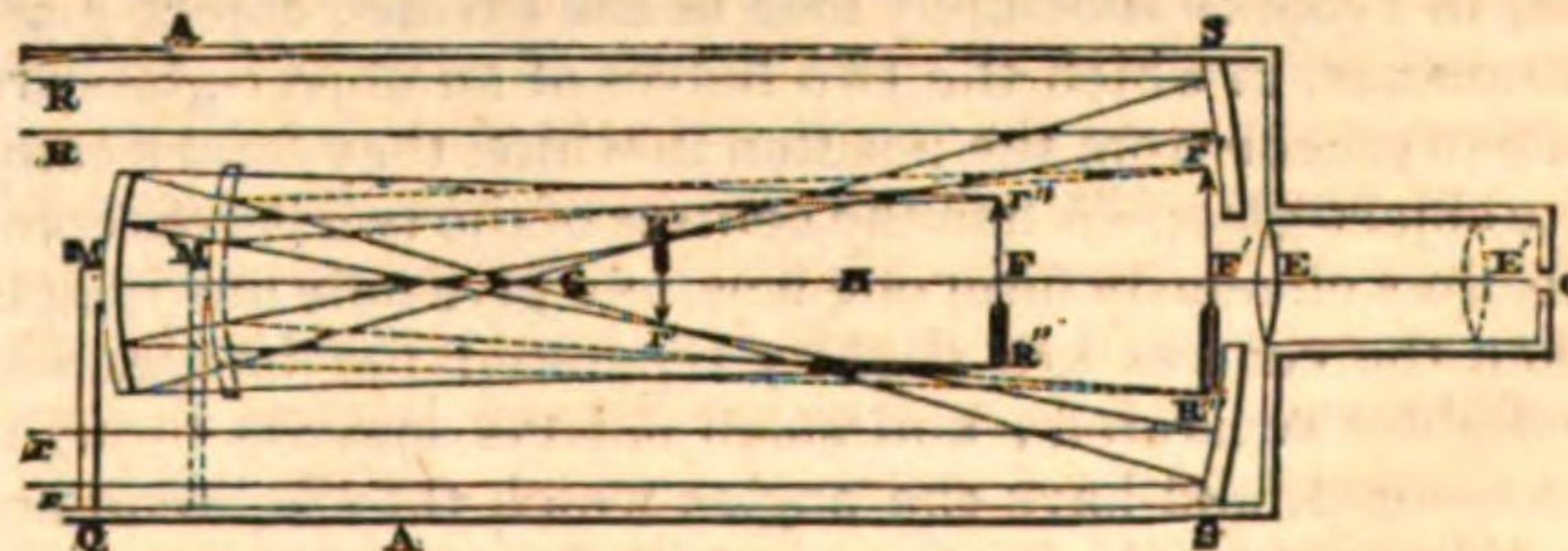
Several pairs of wires placed at different distances might be fixed upon the same diaphragm, or upon separate diaphragms, which could be brought into the focus when wanted; and the second pair of wires might be placed at such a distance that their least angle was equal to the largest angle of the first pair, and so on with the rest.

A wire-micrometer thus constructed is certainly free from almost all the sources of error which affect the common moveable wire-micrometer. The errors arising from the imperfection of the screw, the uncertainty of zero, and other causes, are avoided; and the wires are always equidistant from the centre of the field, so as to be equally affected by any optical imperfection in the telescope. The scale indeed may be formed by direct experiment, and the results will be as free from error as the experiments by which the scale was made.

When this micrometer is applied to a portable telescope, it becomes of great use in naval, military, or geodetical operations, and is employed in measuring distances, either by taking the angle subtended by a body of known dimensions, or by measuring the two angles subtended by a body of unknown dimensions from the two extremities of a known or measured base. For these purposes the telescope is fitted up without a stand, as shown in Plate CCCLVII. fig. 4.

The principle of separating a pair of wires optically is singularly applicable to the Gregorian and Cassegrainian telescopes, where no additional lens or mirror is required. As the magnifying power of both these telescopes may be increased merely by increasing the distance of the eye-piece from the great speculum, and then re-adjusting the small speculum to distinct vision, we can thus vary the angle of a pair of fixed wires by making the eye-piece moveable. This will be easily comprehended from the annexed figure, where SS is the great speculum of a Gregorian reflector, AA the tube, M the small speculum, whose focus is G , and centre of curvature H . It is fixed to an arm MQ , moveable to and from SS in the usual way. The image $R'R''$ is that formed by the speculum SS , and $r''R''$ that

Fig. 4.



formed by the small speculum. This last image being in the focus of the eye-glass E , will be seen distinct and magnified. If the eye-glass E is pulled out to E' , then, in order that the object may be seen distinctly, the image $r''R''$ must be brought into the position $r''R'''$, FF' being equal to EE' ; but this can be done only by advancing the small speculum M to M' , f and F' being now the conjugate

Double-
Image
Microme-
ters.

foci of M. But by this process the magnifying power has been considerably increased, because the part of the whole magnifying power produced by M was equal to $\frac{MF}{Mf}$, whereas it is now $\frac{M'F'}{M'f'}$, a much larger quantity. The angle subtended by the wires has therefore been diminished in the same proportion as the magnifying power has been increased. The scale, in this case, is not one of equal parts, but after the extreme points of it have been determined experimentally, the rest may be filled up either by calculation or direct experiment.

Dr Pearson¹ has, with singular inaccuracy, stated that Sir David Brewster's "patent micrometer is not competent to measure very small angles, even if it had sufficient magnifying power." If he means the patent micrometer as made by Mr Harris, as a naval and military telescope for measuring distances, or as a coming-up glass, he is quite right, because the power of measuring small angles is not required for these practical purposes. But it is quite evident that the *smallest* angles can be measured by the micrometer when fitted up for astronomical purposes. We have only to use a pair of wires placed at a very small distance, or a pair of semi-lenses whose centres are placed at a very small distance, and then vary their angles till it becomes equal to the very small angle which we wish to measure.

CHAP. III.—DESCRIPTION OF DOUBLE-IMAGE MICROMETERS IN WHICH TWO SINGLY REFRACTING LENSES, SEMI-LENSES, OR PRISMS, ARE SEPARATED BY SCREWS.

Röemer.

M. Röemer, the celebrated Danish astronomer, is said to have been the first who suggested the use of a double-image micrometer. He did this about 1678, but the idea does not seem to have been carried into effect, or known to his successors. Nearly seventy years afterwards, viz. in 1743, Mr Servington Savary, of Exeter, communicated to the Royal Society an account of a double-image micrometer; and five years afterwards, in 1748, the celebrated Bouguer proposed the very same construction, which he called a heliometer. This instrument consisted of two lenses, which could be separated and made to approach each other by a screw or other mechanical means. These lenses gave double images of every object; and when the two images of any object, such as the sun or moon, were separated till they exactly touched one another, the distance of the object-glasses afforded a measure of the solar or lunar diameter, after an experimental value of the divisions of the scale had been obtained.

Dollond.

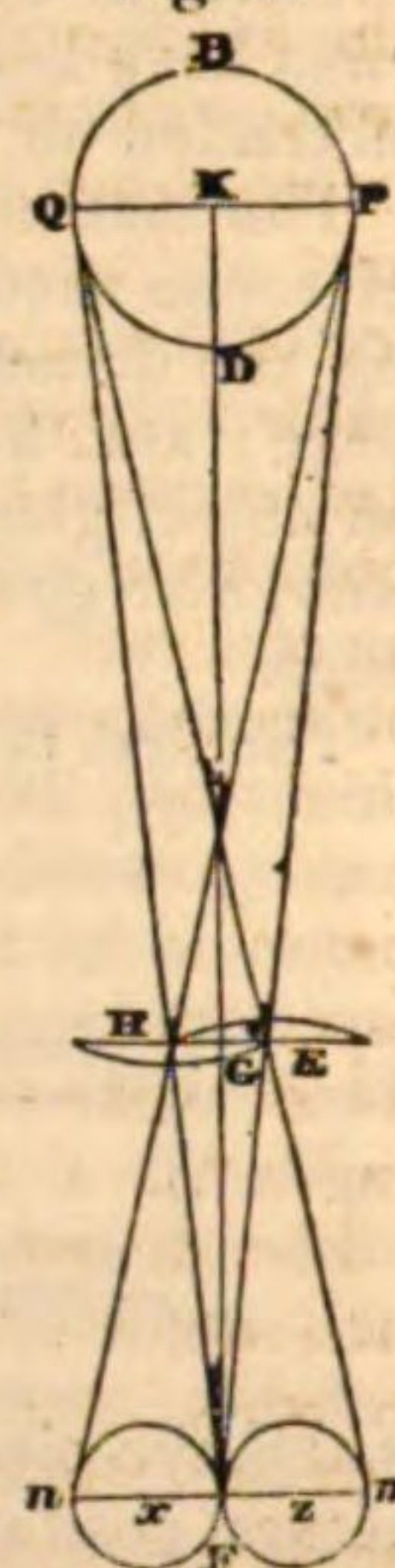
As two complete lenses, however, must always have their least distance equal to the diameter of either, this instrument was incapable of measuring the diameters of small bodies. This obvious defect no doubt led John Dollond, in 1753, to the happy idea of the divided object-glass micrometer, in which the two halves of an object-glass are made to recede from the position in which they form a complete object-glass. When the centres of the two halves coincide, they obviously form one lens, and give only one image. When the centres are slightly separated the images will be slightly separated; and small objects may be brought into contact, and have the angles which they subtend accurately measured. The scale will, therefore, have a zero corresponding to the coincidence of the centres of the semi-lenses. The principle of this instrument will be understood from fig. 5, where H, E are two semi-lenses, whose centres are at H, E, and F their focus. If PQ be a

circular object whose diameter is to be measured, or P, Q two points whose angular distance is to be determined, the lenses are to be separated till the two images x, z are in contact at F. As the rays QHF, PEF pass unrefracted through the centres H, E of the semi-lenses, the angle subtended by QP will be equal to the angle HFE, or that which the distance of the centres of the semi-lenses subtends at F. As the angles, therefore, are very small, they will vary as HE; and when the angles corresponding to any one distance of the centres is determined, those for any other distance will be ascertained by simple proportion.

Mr Dollond, who had not at this time invented the achromatic telescope, applied his micrometer to the object end of a reflecting telescope, as shown in Plate CCCLVII. fig. 5, which represents the micrometer as seen from beyond the object end of the reflector. A piece of tube B, carrying the micrometer, slides into or over the tube A of the telescope, and is fastened to it by a screw. The tube B carries a wheel (not seen in the figure) formed of a ring racked at the outer edge, and fixed to the brass plate CC, so that a pinion moved by the handle D may turn it into any position. Two plates F, G are kept close to the plate CC by the rabbeted bars H, H, but with so much play that they can move in contrary directions by turning the handle E, which drives a concealed pinion that works in the two racks seen in the highest part of the figure. As the two semi-lenses are fixed to the plates F, G, their centres will be separated by the action of the handle E, and their degree of separation is measured by a scale of five inches subdivided into 20ths of an inch, and read off by a vernier on the plate F, divided into 25 parts, corresponding to 24 of the scale, so that we can measure the separation of the semi-lenses to the $\frac{1}{300}$ th of an inch. The vernier is seen to the right of H, and may be adjusted to the zero of the scale, or the position of the lenses when they give only one image, by means of the thumb-screw I, a motion of the vernier being permitted by the screws which fix it to the plate F passing through oblong holes.²

In this construction, the micrometer is too far from the observer, and destroys the equilibrium of the telescope. The instrument itself, however, has more serious defects, as it has been found that the measures of the sun's diameter, taken by different observers, with the same instrument, and at the same time, differ so much as 12 or 15 seconds. This defect has been ascribed to the different states of the observers' eyes, according as they have a tendency to give distinct vision within or beyond the focal point, where the image is most perfect; in the former case the limbs being somewhat separated, and in the latter overlapping. M. Mosotti, in the *Effemeride* of Milan for 1821, has discovered the true cause of this defect, by a series of accurate experiments which he made with this micrometer attached to a Gregorian reflector of two feet in focal length. The focal length of the divided object-glass was 511.3357 inches, or 42 feet $7\frac{1}{3}$ inches. M. Mosotti has shown that a diversity of measures will be obtained by the same observer, if, for the purpose of obtaining distinct vision, he gives a slight displacement to the small speculum by the adjusting screw. If the position of this speculum which gives distinct vision were a point, it would be easy to find that point; but as distinct vision may be obtained within a

Fig. 5.



Double-
Image
Microme-
ters.

¹ Introduction to Practical Astronomy, vol. ii.

² Phil. Trans. vol. xlviii.

Double-
Image
Microme-
ters.

space of 10 or 12 thousandths of an inch, owing to aberration, every different observer will place the mirror at a different point within that range, and consequently obtain a measure corresponding to the image which he views. M. Mosotti recommends that the axis of the adjusting screw, which carries the small speculum, should carry a vernier connected with a scale on the outer surface of the tube A. By means of this vernier the observer is able to give a fixed position to the small speculum, so that he always views the same image, and is thus sure of obtaining the same measure of the same object, so far as the observation is concerned. M. Mosotti found also that the measures were affected by a change of temperature, which, by changing the length of the tube, displaced the small speculum. In his instrument this displacement amounted to 0.0075 of an inch, which, he has shown, corresponds to a change of focal length from 511.3357 to 514.84 inches; and that the error from this cause, upon a length of 30', will be 13" in excess.

The following is Dr Pearson's enumeration of the different sources of error in the divided object-glass micrometer when applied to reflectors.

1. A variation in the position of the small mirror when the eye estimates the point of distinct vision.
2. A displacement of the small mirror by change of temperature.
3. A change of focal distance when central and extreme rays are indiscriminately used. The amount of this error depends on the aberration of the semi-lenses.
4. A defect of adjustment, or of perfect figure, in the two specula, as they regard each other, the measures varying when taken in different directions.

In order to enable Dollond's micrometer to measure differences of declination and right ascension, Dr Maskelyne introduced the aid of cross wires, which he fixed in a moveable ring at the place where the double image is formed. One or both of the two planets or stars are referred to one or other of these lines, as will be seen in the annexed figure, which we take as an example, out of four cases. Let ENWS be the field of view, NS the meridian, and EW the line of east and west; then, in order to obtain the difference of right ascension and declination of two stars, he opened the semi-lenses till he obtained double images of each star. He then turned round the micrometer till the two images of the first star passed over the vertical wire NS at the same instant, and having counted the time that elapsed till the two images of the other star passed over the same line, he had the difference of right ascension in time. By means of the screw which elevated his telescope, and partly by opening the semi-lenses, he made the north image of one star, and the south image of the other, as at A, B, describe in their motion the horizontal wire EW, and at that position of the semi-lenses the scale indicated the difference of declination.

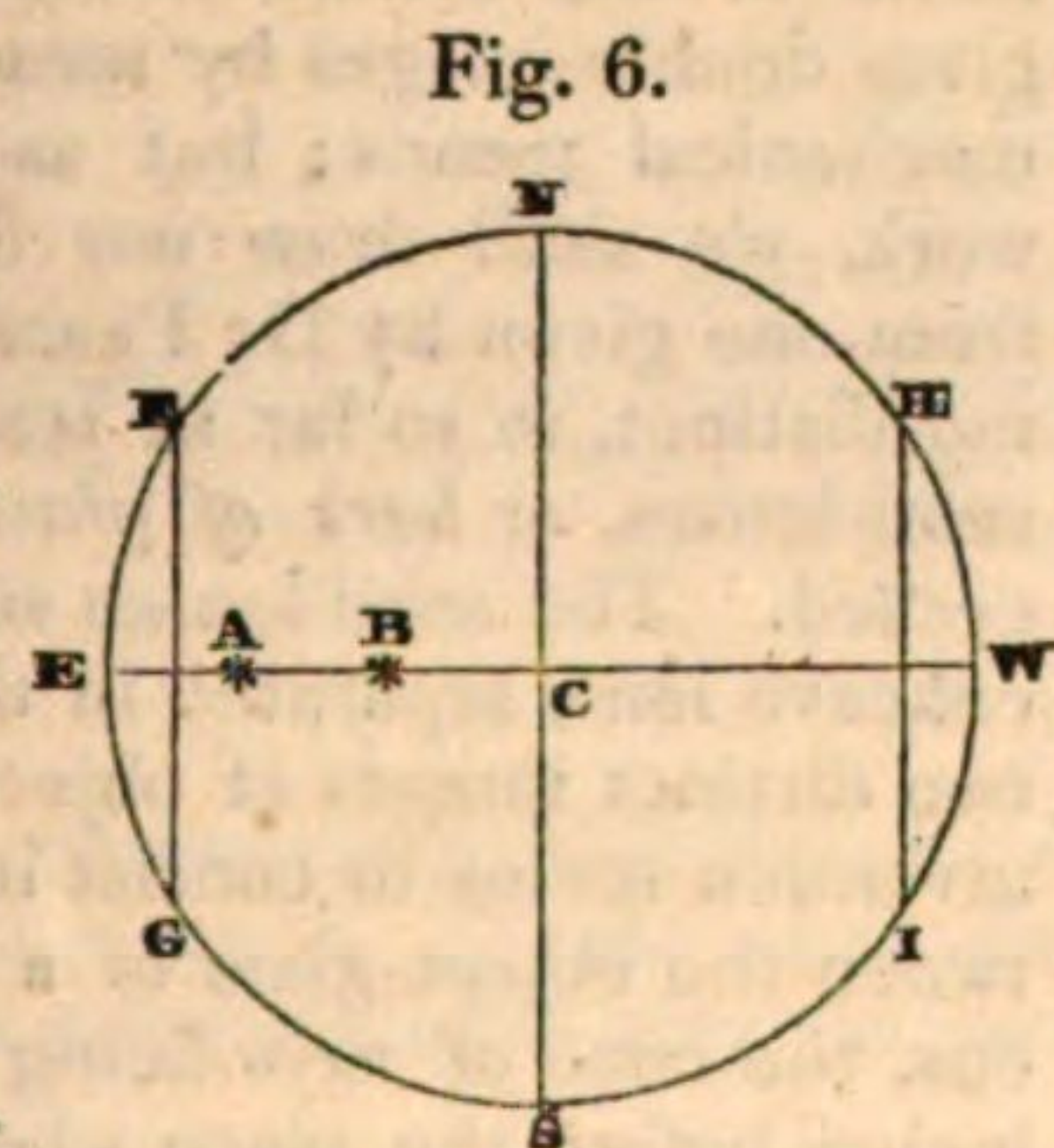


Fig. 6.

A very important improvement upon the divided object-glass micrometer was made by Mr Dollond's son, who adapted it to a refracting telescope, and removed the different sources of error to which it had been found liable. This improvement consists both in the *nature, form, and position* of the semi-lenses. The semi-lenses are made concave, and consist of crown and flint glass, so as to give an achromatic image along with the object-glass of the tele-

scope to which they are applied. These concave semi-lenses, of course, lengthen the focal distance of that object-glass. When a *circular* lens was bisected, as in the old construction, the metallic parts which held the semi-lenses obstructed the light in proportion to their separation; a defect of a serious nature in an instrument. In order to correct this evil, Mr J. Dollond substituted two long slices of glass cut from the diametral portion of a lens nearly six inches in diameter. Hence, in every position of these oblong semi-lenses, none of the metallic setting comes before the object-glass, and consequently the light is never obstructed, and is always of the same amount, whatever be the separation of the lenses. In the old construction, where the diameters of each lens slid along each other in contact, a part of the central portions having been removed by grinding the diameters smooth, the two images of an object never could coincide so as to give an accurate zero; but in the new construction, the space equal to what was removed by grinding is filled up with a brass scale and vernier, and the only evil of this is the loss of light corresponding to the thickness of this scale; but this trifling defect is amply compensated by the perfect coincidence of the images at zero.

This important instrument is shown in Plate CCCLVII. fig. 6, where the same letters are used as in fig. 5 to denote the analogous parts of the two instruments. The end of the telescope is shown at A, and B is the rim of brass, which, by sliding upon A, fixes the micrometer to the telescope. The frame CC', moved by teeth on its outer edge, carries one of the halves G of the lens, and a similar frame with teeth carries the other half F. The scale S, six inches long, is fastened like an edge-bar to CC', and each inch is subdivided into 20 parts, which are read off with a vernier of 25 parts, which is fastened as an edge-bar to the moveable frame that carries F. The two moveable frames are imbedded in a fixed plate HH', screwed to the tube B of the micrometer, and having a circular hole in its middle equal to the diameter of the object-glass. The two semi-lenses are separated by turning the milled head to the right of A, which moves the frame CC', and then the other frame F through the medium of a concealed wheel and a concealed pinion. The mechanism for giving the rotatory motion is also concealed. The adjustment of the vernier to zero is effected by the screw I.

The property which the double-image micrometer possesses, of measuring angles in all directions, directed to it the attention of Ramsden and other eminent opticians. Ramsden accordingly communicated to the Royal Society of London, in 1777,¹ an account of two instruments of this kind, under the name of the *Dioptric* and *Catoptric* Micrometers. In order to avoid the effects of aberration, Ramsden's Ramsden proposed, in his dioptric micrometer, to place two dioptric semi-lenses in the conjugate focus of the innermost lens of the erect eye-tube of a refracting telescope. In place of the imperfections of the lenses being magnified by the whole power of the telescope, they are magnified only about five or six times, and the size of the micrometer glass does not require to be $\frac{1}{100}$ th part of the area which is necessary in Dollond's instrument. This instrument is shown in Plate CCCLVII. fig. 7, where A is a convex or concave lens, bisected in the usual way. One of the semi-lenses is fixed in a frame B and the other in a similar frame E, both of which slide upon a plate H, against which they are pressed by thin plates *a, a*. The milled button D, by means of a pinion and rack, moves these frames in opposite directions; and the separation of the semi-lenses thus effected is measured by a scale of equal parts L on the frame B, the zero being in the middle, and the divisions read off by two verniers at M and N, carried by the frame E; the

Double-
Image
Microme-
ters.

Mr Dol-
lond's im-
prove-
ment.

¹ See Phil. Trans. vol. lxi. 1779, p. 419.

Double-
Image
Microme-
ters.

vernier M showing the relative motion of the two frames when the frame B moves to the right, and N when the frame B is moved to the left. An endless screw F gives the whole micrometer a motion round the axis of vision. This instrument being only the divided object-glass micrometer in miniature, and differently placed, the reader will have no difficulty in understanding its construction and use, from the details already given in the preceding pages.

Dr Pearson informs us, on the authority of Mr Troughton, that a Captain Countess, R. N. having accidentally broken the third lens of a terrestrial eye-piece of his telescope, observed the double images which it produced; and that this observation led to the contrivance of the coming-up glass that was first made by Nairne, with a double screw for separating the halves of the amplifying lens. Hence it is conjectured that Ramsden derived his idea of using a bisected lens for his dioptric micrometer and dynameter. The above facts may be quite true, but Ramsden certainly did not require any such hint, as it was a very natural transition from a bisected object-glass to a bisected eye-glass.

Dr Pearson also states that Mr George Dollond had constructed a dioptric micrometer almost the same as Ramsden's, without knowing any thing of what Ramsden had proposed. We have no doubt that both these ingenious opticians were quite original in their ideas, for it will not be supposed that Captain Countess's broken lens furnished Mr Dollond with the idea of his contrivance. Dr Pearson has given a drawing and description of Mr Dollond's construction of the micrometer as made for Mr Davies Gilbert and himself.¹ It does not appear that Mr Ramsden ever constructed it. The weight of this micrometer was found by Dr Pearson too great for an ordinary achromatic telescope.

Ramsden's
catoptric
microme-
ter.

Mr Ramsden likewise proposed a catoptric double-image micrometer, which, from being founded on the principle of reflection, is not disturbed by the heterogeneity of light, while he considered it as "avoiding every defect of other micrometers," having "no aberration, nor any defect which arises from the imperfection of materials or of execution, as the extreme simplicity of its construction requires no additional mirrors or glasses to those required for the telescope." "It has also, peculiar to itself, the advantages of an adjustment to make the images coincide in a direction perpendicular to that of their motion. In order to effect these objects, Mr Ramsden divided the small speculum of a Cassegrainian reflector into two equal halves, and by inclining each half on an axis at right angles to the plane that separated them, he obtained two distinct images; but as their angular separation was only half the inclination of the specula, which would give only a small scale, he rejected this first idea, and separated the semi-specula by making them turn on their centre of curvature, any extent of scale being obtained by fixing the centre of motion at a proportional distance from the common centre of curvature. The mechanism necessary to effect this is shown in Plate CCCLVII. fig. 8, where A is the bisected speculum, one of the semi-specula being fixed on the inner end of the arm B, its outer end being fixed on a steel axis X extending across the mouth of the tube C. The other semi-speculum is fixed on the inner end of the arm D, its outer end terminating in a socket y, which turns upon the steel axis x. These arms are braced by the bars a, a. A compound screw G, having its upper part cut into double the number of threads in an inch, viz. 100, to the lower part g, which has only 50, works with the handle in a nut F in the side of the tube, while the part g turns in a nut H fixed to the arm B. The point of the compound screw separates the ends of the arms B and D, and, pressing against the stud

h fixed to the arm D, turns in the nut H on the arm B. A spiral spring within the part n presses the two arms B, D against the direction of the double screw e g, so as to prevent all shake or play in the nut H. The progressive motion of the screw through the nut will be half the distance of the semi-specula, so that these specula will be moved equally in opposite directions from the axis of the telescope.

A graduated circle V, divided into 100 parts on its cylindrical surface, is fixed on the upper end of the screw G, so as to cause it to separate the semi-specula. The fixed index I shows the parts of a revolution performed by the screw, while the number of whole revolutions of the screw is shown by the divisions of the same index. A steel screw R, moveable by a key, inclines the small speculum at right angles to the direction of its motion. Distinct vision is procured in the usual manner, and the telescope has a motion about its axis, in order to measure the diameter of a planet in any direction; and the angle of rotation in reference to the horizon is shown by a level, graduated circle, and vernier, at the eye end of the large tube.

A catoptric double-image micrometer has been suggested by Sir David Brewster as applicable to the Newtonian telescope. The plane mirror is bisected, and is made to form two images, either by giving each semi-speculum a motion round their common line of junction, or round a line perpendicular to that common line. The mechanism by which this may be effected does not require any description. If the micrometer is required for the sun or any luminous body, the small mirror may be made of parallel glass, which would have the advantage of not obstructing any of the light which enters the telescope, while it reflects enough for the purposes of distinct vision. We shall again have occasion to refer more particularly to this idea in the next section.

Double-
Image
Microme-
ters.

Catoptric
microme-
ter for a
Newtonian
telescope.

Professor Amici of Modena has described, in the Memoirs of the Italian Society, a new micrometer, which gives double images by means of semi-lenses separated by mechanical means; but as we have not access to this work, we shall draw our description of the instrument from one given by Dr Pearson, which is very far from being distinct, in so far at least as the construction of the semi-lenses, or *bars of glass* as they are called, are concerned. The semi-lenses seem to be portions of a large concave lens, separated in the usual manner, so as to give two distinct images of objects; but the peculiarity of the invention seems to consist in the lenses being placed between the object-glass of a telescope and its principal focus, the cone of rays being divided at a point about six inches before the place where the focal image is formed. Dr Pearson, who made experiments with one of these instruments, has hinted at the inconveniences which he experienced in using it.

Amici's
microme-
ter.

CHAP. IV.—DESCRIPTION OF DOUBLE-IMAGE MICROMETERS IN WHICH THE TWO IMAGES FORMED BY TWO SIMPLY REFRACTING LENSES, SEMI-LENSES, OR PRISMS, ARE SEPARATED OPTICALLY.

In the year 1776 Dr Maskelyne constructed and used his prismatic micrometer, which he had contrived with the view of getting rid of the sources of error to which he found the divided object-glass micrometer liable. Having cut a prism or wedge of glass into two parts, so as to form two prisms of exactly the same refracting angle, he conceived the idea of fixing them together, so as to produce two images, and to vary the angle which these two images formed, by making the prisms move between the ob-

Maskelyne's
prismatic
micrometer.

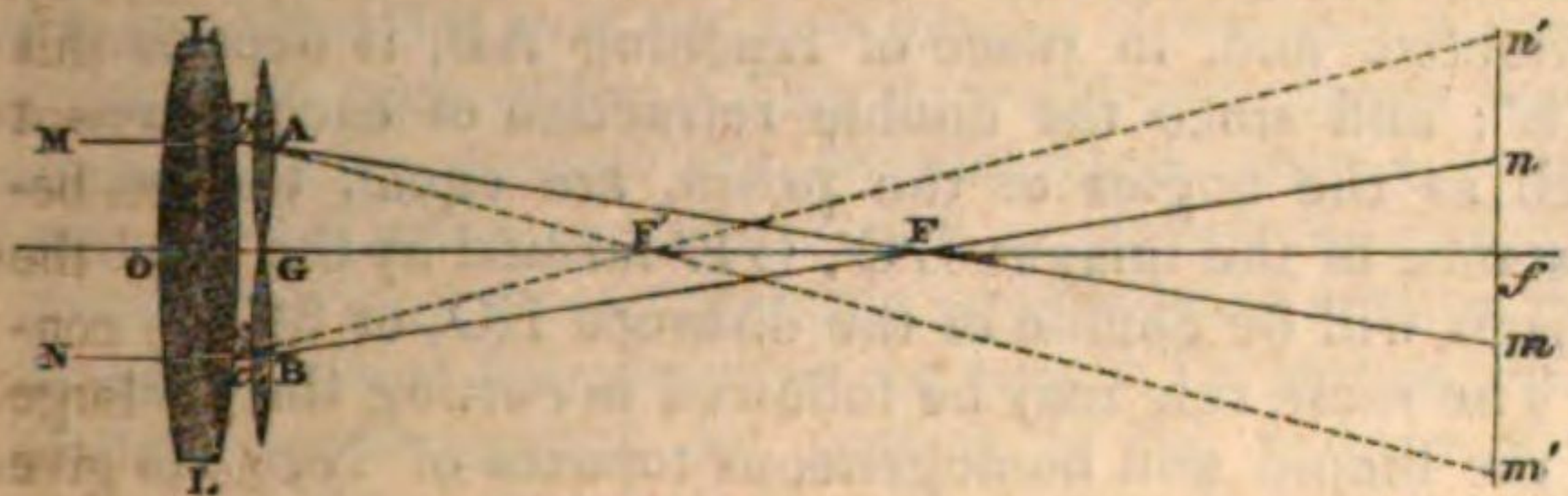
¹ Introduction to Practical Astronomy, vol. ii. p. 182.

Double-Image Micrometers. — ject-glass and its principal focus; so that the scale is equal to the whole focal length of the telescope. The two prisms may be placed in three ways, with their thin edges joined, with their square thick edges or backs joined, or with their sides or triangular edges joined. In the first position the double images will have only one half of the light which is incident on the object-lens when the prisms are close to it, and their degree of illumination will diminish as they approach the focus. In the second position they will, as before, have only one half of the incident light when close to the object-glass, but the illumination will gradually increase as the prisms advance to the focus. In the third case, the prisms being in a reverse position, the light will be the same in every part of the scale, each of them receiving half the rays which fall upon the object-glass. On this account Dr Maskelyne preferred this last arrangement.

In the instrument which Dr Maskelyne constructed, and which seemed to have had only a thirty-inch object-glass, the prisms were not achromatic, and consequently the touching limbs of a luminous body were affected with the prismatic colours. In the case of the sun, where all the rays might have been absorbed but the red, this was of little consequence; but in other cases it was a serious defect, which could be removed only by making the prisms achromatic; or it might have been diminished by making the prisms of fluor spar, in which the dispersion is very small. One of the Dollonds, accordingly, executed for Dr Maskelyne an achromatic prism, which performed well. It does not appear that Dr Maskelyne made any observations of value with this instrument.

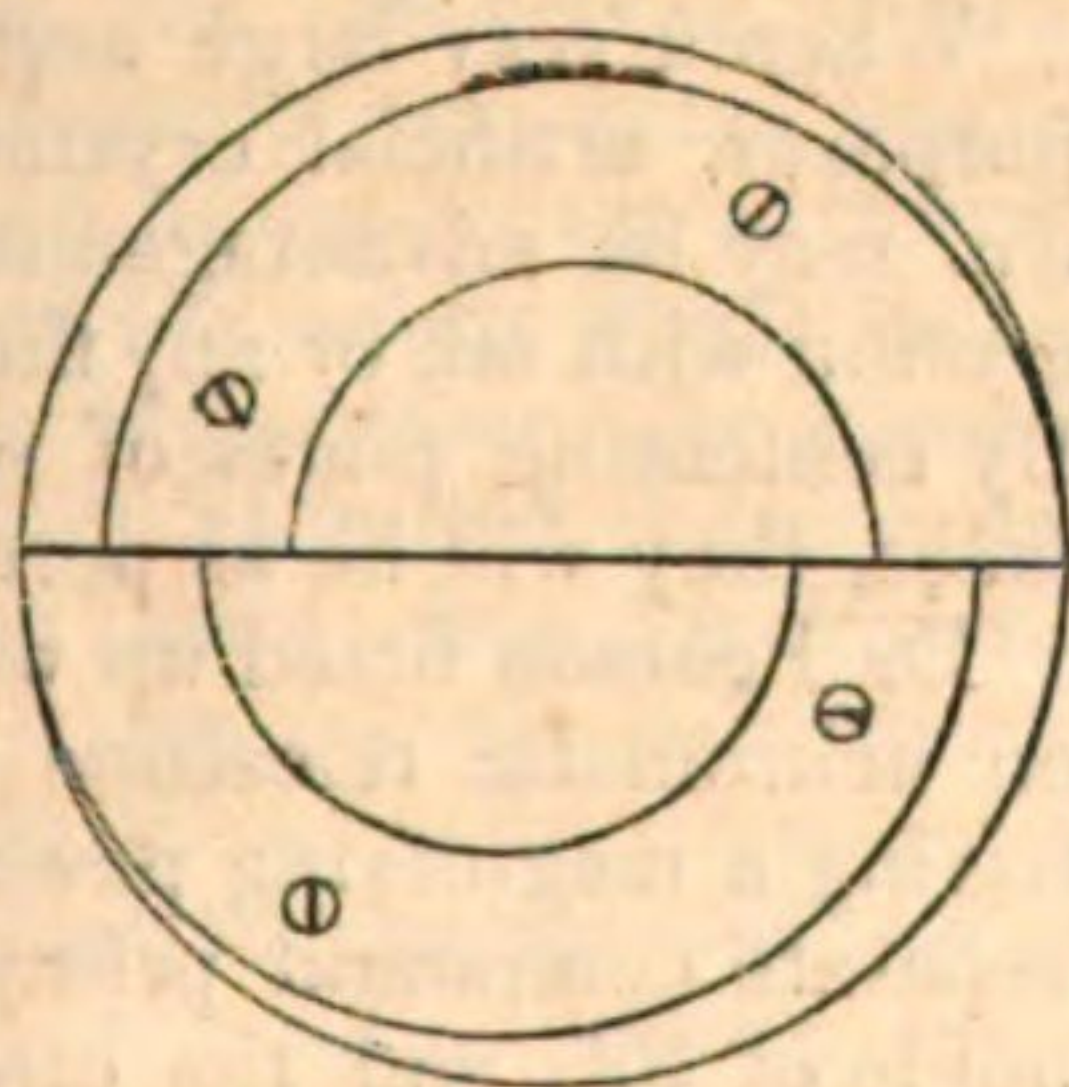
New divided object-glass micrometer. — A new divided object-glass micrometer has been constructed by Sir David Brewster, and described in his Treatise on New Philosophical Instruments. It consists of an achromatic object-glass LL, fig. 7, between which

Fig. 7.



and its principal focus f two achromatic semi-lenses, fixed at a given distance, are made to move. These lenses are shown in fig. 8, and are fixed on a piece of tube, which screws into a tube; by pulling out and pushing in which, they are made to recede from or approach to the object-glass LL. By this motion the angle subtended by the two images varies in the same manner as the angle subtended by a pair of fixed wires was made to vary by the motion of a second object-glass. When the semi-lenses are close to LL, as shown at A, B, fig. 7, the two images which they form are much separated, and their centres subtend a large angle; but as the lenses approach to f , the centres of the images gradually approach each other, and consequently the angle which they subtend continually increases. Hence, if we determine by experiment the angular distance of their centres when the lenses are close to LL, and likewise the angle when they are at f , the other end of the scale, and if we fill up the intermediate points of the scale either from theory or direct experiment, we shall

Fig. 8.

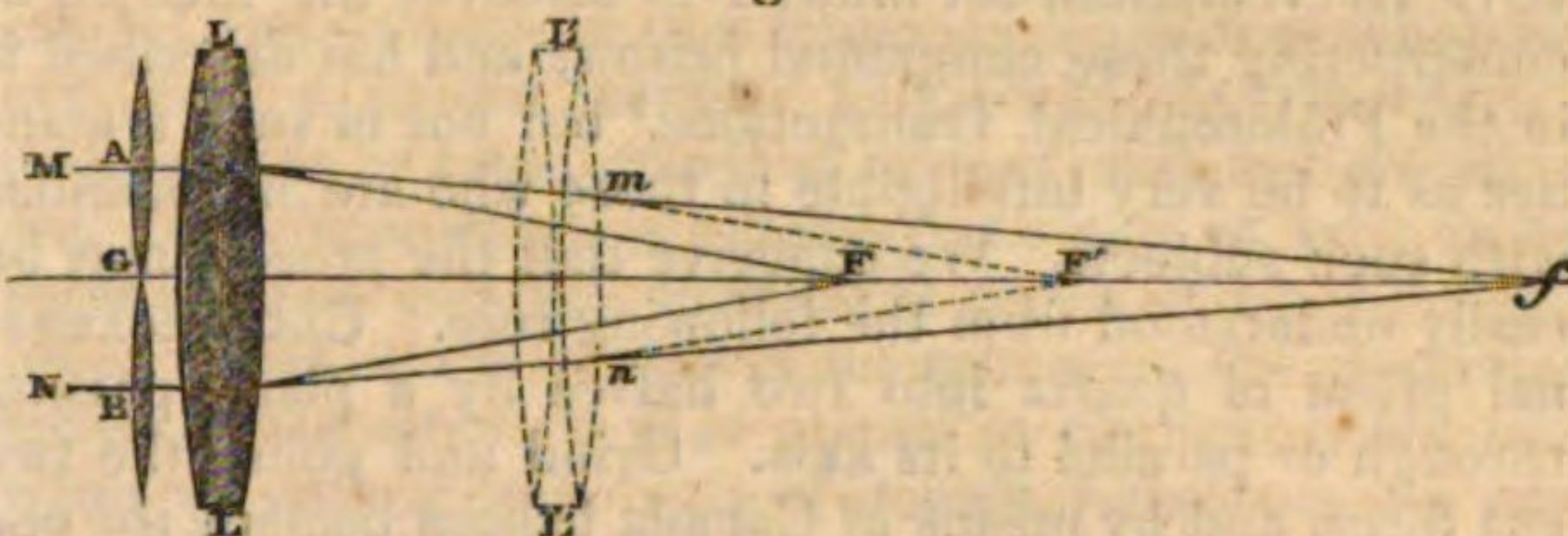


have an instrument which will measure with the greatest accuracy all angles between the two extreme ones. Another or more pair of semi-lenses may be used in the same telescope, and placed at smaller or greater distances, so that, by means of other scales adapted to them, we may obtain all angles that may be required. The lenses A, B may be concave or convex; and when a large scale is required, with a tenth of an inch to a second, or even greater, we have only to use semi-lenses of long foci, and the scale may be confined to the part of the tube nearest the focal point.

Sir David Brewster has proved, both from theory and experiment, that the scale is one of equal parts; so that, after having ascertained by experiment the two extreme angles, the whole scales may be completed by dividing the interval into any number of equal parts, and these subdivided, if necessary, by a vernier scale.

When the semi-lenses are placed without the object-

Fig. 9.



glass LL, and this object-glass moved towards f , as in the annexed figure, the angular distance of the images is invariable.

This instrument has been constructed for measuring distances, and as a coming-up glass for ascertaining whether a ship is approaching to or receding from the observer. In this form it constitutes part of fig. 4, Plate CCCLVII., the semi-lenses being made to screw into the same place as the second object-glass, and having a separate scale for themselves. In this form many of the instruments have been constructed by Tulley.

Among the optical micrometers, we may describe another invented by Sir David Brewster, and adapted solely to the Newtonian telescope. In order to get rid of the loss of light by the reflection of the small plane speculum, he uses an achromatic prism to reflect the light just as much out of the axis of the telescope as will allow the head of the observer to be applied to the eye-tube, without obstructing any of the light which enters the tube. By using two prisms, as in Maskelyne's instrument, and moving them along the axis of his telescope through a small distance, we shall obtain a good micrometer. The prisms may be separated mechanically, or a doubly refracting prism may be fixed upon the face of the single or achromatic prism used to turn aside the rays. The achromatism of a single glass prism may be corrected by the doubly refracting prism, a balance of refraction being left sufficient to turn aside the image to the observer's eye.

CHAP. V.—DESCRIPTION OF DOUBLE-IMAGE MICROMETERS IN WHICH THE TWO IMAGES ARE FORMED BY DOUBLE REFRACTION.

The happy idea of applying the two images formed by double refraction to the construction of a micrometer unquestionably belongs to the Abbé Rochon; and though Dr Pearson has laboured to show that Dr Maskelyne's prismatic telescope was constructed before Rochon's, yet this does not in the smallest degree take away from the originality and priority of Rochon's invention; for the idea of varying the angle by the motion of the prisms can scarcely be viewed as an essential part of the invention.

Double-Image Micrometers.

Prismatic micrometer for Newtonian reflectors.

first micrometer.

Double-
Image
Microme-
ters.

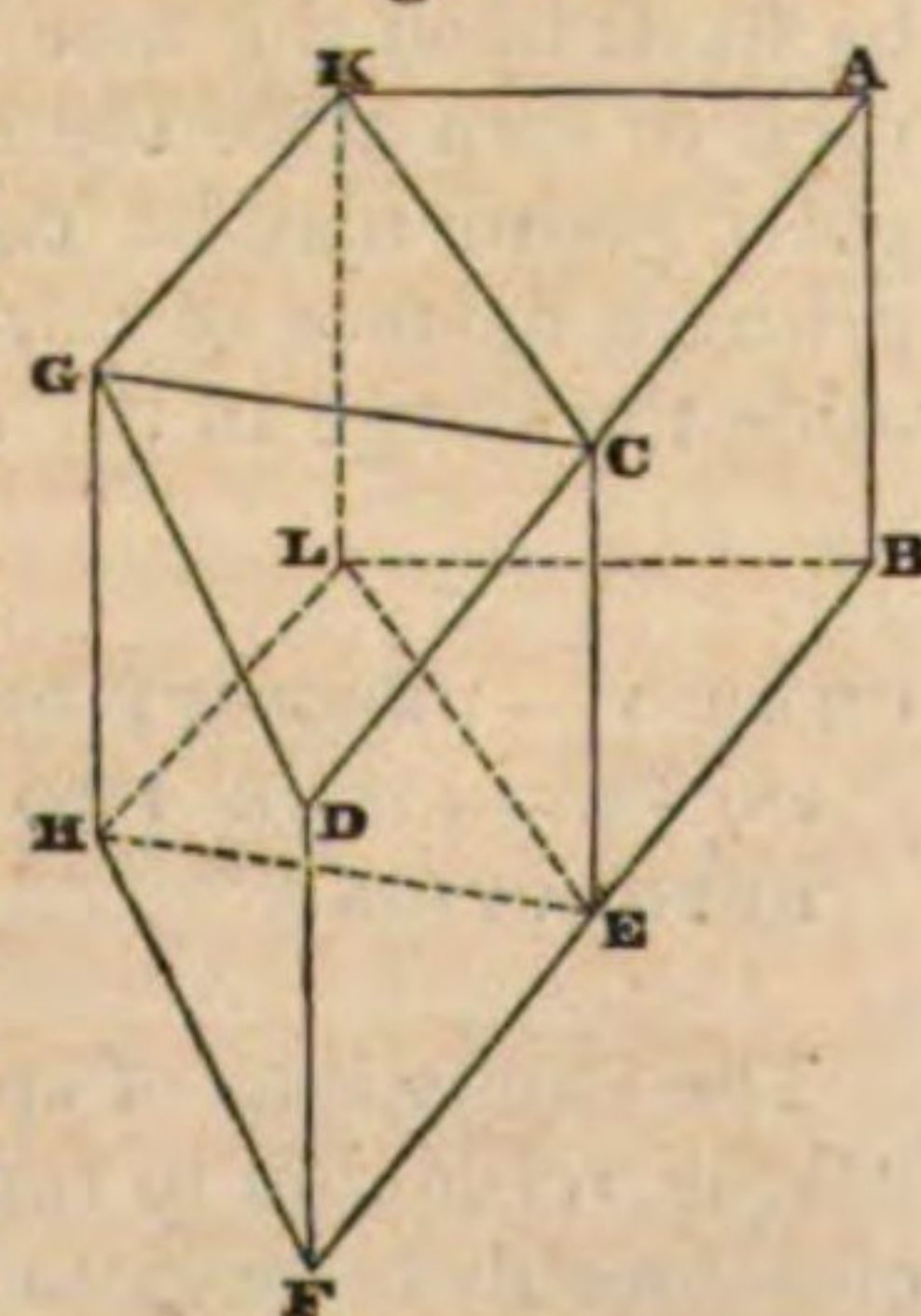
Rochon's
first micro-
meter.

Although the double refraction of rock-crystal is small, yet, from its limpidity and hardness, the Abbé Rochon regarded it as superior to any other substance for making doubly refracting prisms. When he used one prism so cut that its refracting edge coincided with the axis of the prism, in which case its double refraction was the greatest, he found that the separation of the two images was too small to give the angles which he required.¹ He therefore fell upon a most ingenious plan of doubling the amount of the double refraction of one prism, by using two prisms of rock-crystal, so cut out of the solid as to give each the same quantity of double refraction, and yet to double that quantity in the effect produced. This construction of the compound prism was so difficult, that M. Rochon informs us, that "he knew only one person, M. Narci, who was capable of giving rock-crystal the prismatic form in the proper direction for obtaining the double refractions necessary to the goodness of the micrometer." The method used by Narci seems to have been kept a secret, for in 1819 Dr Wollaston set himself to discover the method of constructing these compound prisms, and has described it in the *Philosophical Transactions*,² but not in such a manner as to be very intelligible to those who are not familiar with such subjects. We conceive that the process may be easily understood from the following rule. Cut a hexagonal prism of quartz into two halves by a plane passing through or parallel to its axis. Grind and polish the two cut faces, and by means of Canada balsam cement the one upon the other, so that any line or edge in the one face may be perpendicular to the same line in the other. Cut and polish a face on each of the united portions, so that the common section of these faces with the cemented planes may be parallel to the axis of the crystal, while they are equally inclined to these planes, and the prism will be completed.

Method of
cutting the
prisms
from the
crystal.

We shall now explain, by a diagram, a more simple and economical way of cutting these prisms, though the principle is exactly the same. Let AKGDBLHF be half of a hexagonal prism of quartz, the height of which, DF, is equal to half of its diameter AD. Bisect AD in C, and join CK, CG, and draw CE parallel to AB or DF. This line CE will be the axis of the prism. Grind and polish the section ABFD, and cut off the prisms AKCBLE and DGCFFE, setting aside the intermediate similar prism KGCLHF. The faces ACEB, DCEF are square and equal, so that if we cement these faces together, making the line AB coincide with FE, AC will coincide with FD, CE with CF, and EB with CF. If we wish each prism to have an angle of 60° , we may take either GDFH or GCEH for the refracting face of it; we shall suppose the former. In this case we must grind and polish a face on the other prism ABL, which is accurately parallel to the face GDFH, and the compound prism will be completed. If 60° is too great, we must grind down the face GDFH till it has the desired inclination to DF, and grind and polish a face parallel to it on the other prism. The external faces, in short, to be made upon each prism, must be equally inclined to the cemented planes DCEF, ABEC, and have their common section DF parallel to the axis CE of the prism.

Fig. 10.



In place of cutting off the prism AKCBLE, we may cut off only the prism GCDHEF, leaving the intermediate one KGCLHE attached to AKCBLE, and proceed as before. The object of this is to leave enough of solid quartz at KL to give a face of the same breadth as GDFH. If the prisms required are small compared with the quartz crystal, we may obtain, by the first method, six prisms out of the crystal, or three pair of compound ones. On the other hand, if the required prism is large compared with the crystal of quartz, it may require one half of the crystal to make one prism, and the other half the other. Nay, it may be necessary to cut each individual prism out of separate crystals, the method of doing which is very obvious from the preceding description.

When the prism is completed, it is obvious that a ray of light incident perpendicularly on the face GHFD will be perpendicular to the axis of the prism CE, and therefore the extraordinary ray will suffer the greatest deviation, viz. $17'$; and the same is true of the other prism. But when the ray passes through both, it is found to have a deviation of $34'$, which is produced in the following manner: Let AB be a line viewed through one of the prisms, with its refracting angle turned upwards; two images of it will be seen, viz. the extraordinary image at E, and the ordinary one at O.

If we now interpose the other prism with its refracting angle downwards, both these images E, O will be refracted downwards. But, owing to the transverse cutting of the prisms, the extraordinary image E, which was most raised, now suffers ordinary refraction, and is least depressed, so that in place of being refracted back to AB, it comes only to E'O'. On the other hand, the ordinary image O, which suffered the least refraction, is now extraordinarily refracted, and, in place of reaching AB, is depressed to O'E'; and since the double refraction of each prism, as well as the angles of the prism, are equal, the angular distance of the images E'O', O'E' formed by the combined prisms will be double of the distance EO, or $34'$.

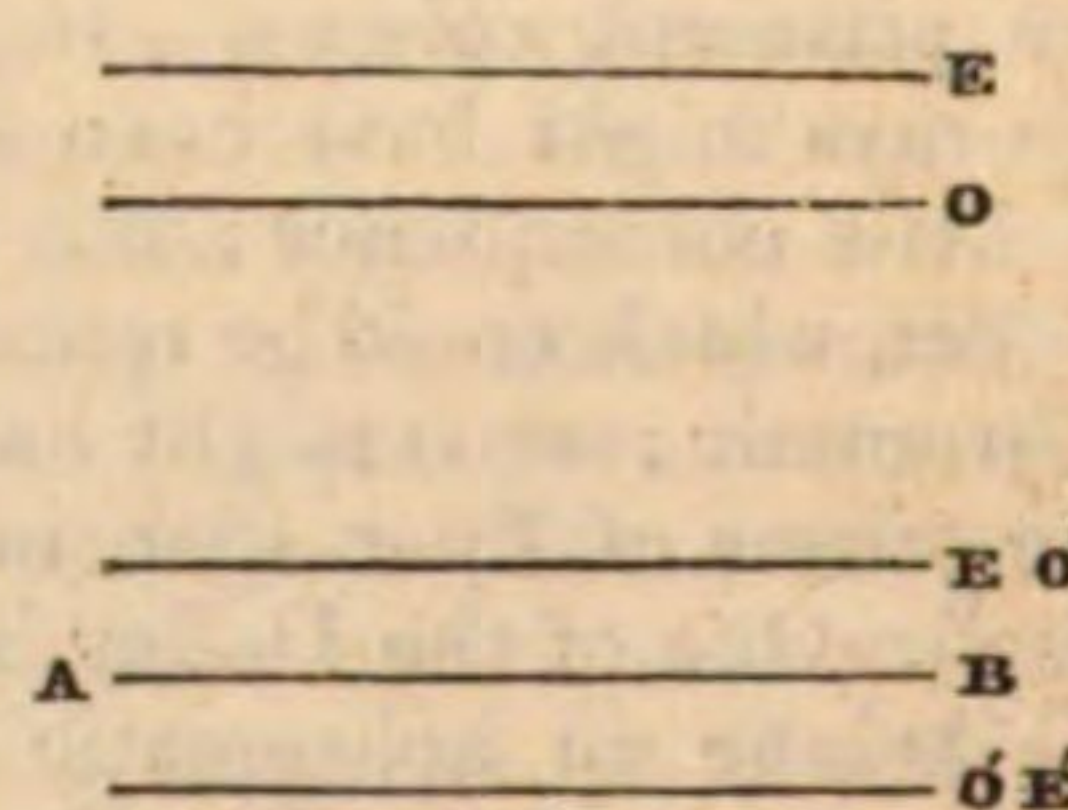
The same rule may be followed in cutting the prism out of the limpid and homogeneous topazes of New Holland, the principal axis of which coincides with the axis of the prism. When the crystals are amorphous, the cleavage planes will be a sufficient guide, as the above axis is always perpendicular to them. Such prisms are incomparably superior, as we have practically experienced, to those made of rock-crystal.

When a very large angle is required for any particular purposes, artificial crystals, such as carbonate of potash, &c. may be advantageously employed, the crystals being ground with oil, or any fluid in which they are not soluble. By cementing plates of parallel glass on their outer surfaces, they will be as permanent as rock-crystal.

Dr Pearson fitted up with one of Rochon's micrometers an achromatic telescope 33 inches in focal length, and having a magnifying power of $35\frac{1}{2}$. He applied to it two separate compound prisms, one of which had a constant angle of $32'$, and the other an angle only of $5'$, the vernier in the former case indicating seconds, and in the latter tenths of seconds. A drawing is given of the tube, with the prisms and scales, in Plate CCCLVII. fig. 9 and 10, as given by Dr Pearson. The tube is graduated from the

Double-
Image
Microme-
ters.

Fig. 11.



¹ In his first experiments Rochon corrected the dispersion of the rock-crystal prism by a similar prism placed in front of it, and having its exterior face perpendicular to the axis of the crystal. This prism, having no effect in doubling the image, gave him a complete correction of the dispersion for the ordinary image.

² Phil. Trans. 1820, p. 126.

Double-
Image
Microme-
ters.Double-
Image
Microme-
ters.

solar focus into two scales, one being placed on each side of the slit or opening cut along the middle of the tubes, to allow the sliding piece, shown separately in fig. 10, to move from the object-glass to the solar focus. This sliding piece holds the prism, the larger prism of 32' being shown as placed with its sliding piece in the tube, and the smaller prism of 5' being shown in the separate sliding piece, fig. 9. The two verniers of the scales are seen on each side of the two screws with milled heads, which pass through the slit, and serve to move the sliding piece to or from the object-glass when they are not too much tightened.

In his original memoir on the subject, published in the *Journal de Physique* for 1801,¹ M. Rochon makes the following observations. "I ought not to omit, that in this new construction there are difficulties of execution not easy to surmount, which may have been one reason why these instruments, so useful to navigators, and in certain very nice astronomical observations, have not been adopted. This induced me at length to adopt Euler's method. In the construction of achromatic object-glasses I found I could increase or diminish the absolute effect of the double refraction within certain limits, by means of the interval between the glasses of different refracting powers; the separation of the images at the focus being so much the greater, as the interval is larger, when the flint-glass is the first of the object-glasses, and less when it is the second. Conformably to these new principles, I have had two telescopes with a doubly refracting medium constructed under my own inspection, which General Gantheaume will employ for determining the position of his ships, and to find whether he be approaching any he may meet with at sea."²

Rochon's
second mi-
crometer.

In 1812 M. Rochon constructed his doubly refracting micrometer in another form, from which he anticipated great advantages. He made a parallelopiped of rock-crystal, consisting of two prisms whose refracting angles were each about 30°, so that the angle which they gave was less than 30', and the two images of the sun of course overlapped each other. The prisms being firmly united by mastic, he ground the parallelopiped into a convex lens, so that when combined with a concave one of flint-glass, it formed an achromatic object-glass with a focal length of about 3 decimetres, or nearly 12 inches. This object-glass separated the centres of the images of the sun about 28 minutes. "He then adapted to this object-glass a common micrometer, which measured angles of 10 minutes, and he had thus 3 decimetres and 10 minutes to complete the measure of the diameters of the sun or moon."³

M. Arago's
microme-
ter.

M. Arago appears to have been the first person to apply doubly refracting prisms to the eye-pieces of telescopes for the purpose of measuring very small angles. He explained his general method to the writer of this article in July 1814, and mentioned the results which he had obtained with it in measuring the diameters of the planets. We do not recollect distinctly how he varied the constant angle of the doubly refracting prism; but Dr Pearson and M. Biot state,⁴ that the constant angle was increased by placing the prism in an oblique direction as regards the line of vision; and "that he determined the respective values of the angles thus increased by means of concentric circles placed vertically at a measured distance from the eye when looking through the prism; for as he knew the diameters of each circle, he could generally find

one out of the number which would come into exact contact with its image, and thus give the value of the constant angle."⁵

Dr Pearson has proposed an *ocular crystal micrometer*, and has given a drawing and description of the instrument.⁶ It is nothing more than M. Arago's ocular crystal prism, in which the constant angle is varied by Sir David Brewster's variable eye-piece already described. On the same principle, the angle of the prism may be varied by a convex or concave lens moving between the object-glass and its principal focus; but what would be still better, by pulling out or pushing in the eye-piece of a Gregorian or Cassegrainian telescope.

In 1821 Mr George Dollond communicated to the Royal Society an account of his spherical crystal micrometer, a very ingenious instrument, though, we should think, one difficult to execute; and, at the same time, even when well executed, liable to error. Mr Dollond's improvement consists in making a sphere or lens from a piece of rock-crystal, and adapting it to a telescope in place of the usual eye-glass, as shown in Plate CCCLVII. fig. 11, where *a* is the sphere or lens, formed of rock-crystal, and placed in half holes, from which is extended the axis *bb*, with an attached index, the face of which is shown in fig. 12. This index registers the motion of the sphere on the graduated circle. The sphere *a* is so placed in the half holes, that when its natural axis (axis of double refraction, we presume) is parallel to the axis of the telescope, it gives only one image of the object. In a direction perpendicular to that axis, it must be so placed that when it is moved the separation of the images may be parallel to that motion. The method of acquiring this adjustment is by turning the sphere *a* in the half holes parallel to its own axis. A second lens *d* is introduced between the sphere and the primary image given by the object-glass, and its distance from the sphere should be in proportion to the magnifying power required. The magnifying powers engraven in fig. 12 are suited to an object-glass of 44 inches focal length. The following are the advantages of this construction, as stated by its inventor. 1. It is only necessary to select a piece of perfect crystal, and, without any knowledge of the angle that will give the greatest double refraction, to form the sphere of a proper diameter for the focal length required. 2. The angle may be taken on each side of zero, without reversing the eye-tube; and intermediate angles may be taken between zero and the greatest separation of the images, without exchanging any part of the eye-tube, it being only required to move the axis in which the sphere is placed. 3. It possesses the property of a common eye-tube and lens; for when the axis of the crystal is parallel to that of the object-glass, only one image will be formed, and that as distinctly as with any lens that does not refract doubly.⁷

Dr Pearson had one of these instruments constructed by Mr Dollond, and applied to an achromatic object-glass 43.6 inches in focal length. He has shown that the scale is not one of equal parts, and has pointed out a method of determining the constant angle of the crystal.

Knowing from experience the imperfect structure of rock-crystal, especially in directions approaching to the axis, we dreaded that a spherical eye-glass of this material would not give perfect vision. Dr Pearson confirms this opinion by actual observation. He attempted to measure the diameter of Mars when about 9", "but its limits were

¹ Translated in Nicholson's Journal, 8vo, vol. iv. p. 110-120.

² This description is not very intelligible, but we cannot at present refer to the original memoir.

³ Introduction to Practical Astronomy, vol. ii. p. 206-212.

⁴ We regret that M. Arago has, in so far as we know, not published an account of his methods. What Dr Pearson says is not very intelligible. We presume his meaning to be, that M. Arago made his scale for measuring the varying angle of the images by direct experiment.

⁵ Introd. Pract. Astron. vol. ii. p. 219.

⁶ Ibid. p. 117.

⁷ See Phil. Trans. 1821, p. 101-104.

Position Micrometers. so imperfectly defined that no satisfactory observation could be made."¹ We would therefore strongly recommend to Mr Dollond the substitution of limpid topaz from New Holland, in place of the rock-crystal.

CHAP. VI.—DESCRIPTION OF POSITION MICROMETERS.

Position micrometers.

Sir W. Herschel's position micrometer.

A position micrometer is an instrument for measuring angles when a plane passing through the two lines which contain these angles is perpendicular to the axis of vision. Sir W. Herschel first proposed such an instrument for the purpose of verifying a conjecture, that the smaller of the two stars which compose a double star revolves round the larger one. Hence it became necessary to observe if a line joining the centres of any two stars always formed the same angle with the direction of its daily motion. After constructing the instrument which we are about to describe, and making a long series of observations, he verified his conjecture by the important discovery, that the double stars formed binary systems, in which the one revolved round the other.² The position micrometer used by Sir William Herschel in his earliest observations, viz. those made in 1779–1783, was made by Nairne, and was constructed as shown in Plate CCCLVII. fig. 13, which represents it when enclosed in a turned case of wood, and ready to be screwed into the eye-piece of the telescope. "A is a little box which holds the eye-glass. B is the piece which covers the inside work, and the box A screwed into it. C is the body of the micrometer, containing the brass work, showing the index-plate *a* projecting at one side, where the case is cut away to receive it. D is a piece having a screw *b* at the bottom, by means of which the micrometer is fastened to the telescope. To the piece C is given a circular motion, in the manner the horizontal motion is generally given to Gregorian reflectors, by the lower part going through the piece D, where it is held by the screw E, which keeps the two pieces C and D together, but leaves them at liberty to turn on each other. Fig. 14 is a section of the case containing the brass work, where may be observed the piece B hollowed out to receive the box A, which consists of two parts enclosing the eye-lens. This figure shows how the piece C passes through D, and is held by the ring E. The brass work, consisting of a hollow cylinder, a wheel and pinion, and index-plate, is there represented in its place. F is the body of the brass work, being a hollow cylinder with a broad rim C at its upper end; this rim is partly turned away to make a bed for the wheel *d*. The pinion *e* turns the wheel *d*, and carries the index-plate *a*. One of its pivots moves in the arm *f*, screwed on the upper part of *c*, which arm serves also to confine the wheel *d* to its place on *c*. The other pivot is held by the arm *g* fastened to F.

A section of the brass work is shown in fig. 15, where the wheel *d*, which is in the form of a ring, is laid on the upper part of F or C, and held by two small arms *f*, *h*, screwed down to *c* with the screws *i*, *i*.

A plan of the brass work is shown in fig. 16, where *d* is the wheel placed on the bed or socket of the rim of the cylinder *cc*, and is held down by the two pieces *f*, *h*, which are screwed on *cc*. The piece *f* projects over the centre of the index-plate to receive the upper pivot of the pinion *mn*, the fixed wire being fastened to *cc*, and the moveable wire *op*, fastened to the annular wheel *dd*. The index-plate *a*, milled on the edge, is divided into sixty parts, each subdivided into two. When the finger is drawn over the milled edge of the index-plate from *q* to

r, the angle *mso* will open, and if drawn from *r* towards *q*, it will shut again. The case *cc* must have a sharp corner *t*, which serves as an index to point out the divisions on the index-plate.³

We do not know the value of the divisions in the instrument used by Sir William Herschel; but in the position micrometer of the five-feet equatorial used by Sir John Herschel and Sir James South, in their observations on double stars, the position circle was large enough to show distinctly minutes of a degree by means of its vernier.

The position micrometer which we have now described has been greatly improved by Sir David Brewster; and the following account of these improvements, which is not susceptible of abridgment, is given in his own words.

In the position micrometer invented by Sir William Herschel, "the two wires always cross each other at the centre of the field, and consequently their angular separation is produced uniformly by the motion of the pinion. This very circumstance, however, though it renders it easy for the observer to read off the angle from the scale, is one of the greatest imperfections of the instrument. The observations must obviously be all made on one side of the centre of the field, as appears from fig. 16; and the use of the instrument is limited to those cases in which *Ss* is less than the radius *SC*. The greatest disadvantage of the instrument, however, is the shortness of the radius *SC*; for the error of observation must always diminish as the length of this radius increases. This disadvantage does not exist in measuring the angle of position of two stars *S*, *s*, for the distance *Ss* remains the same whatever be the length of *SC*; but in determining the angle which a line joining two stars forms with a line joining other two stars, or those which compose a double star (an observation which it may often be of great importance to make), and all other angles contained by lines whose apparent length is greater than *SC*, this imperfection is inseparable from the instrument. Nay, there are some cases in which the instrument completely fails; as, for instance, when we wish to measure the angles formed by two lines which do not meet in a focus, but only tend to a remote vertex. If the distance of the nearest extremities of these lines is greater than the chord of the angle which they form measured upon the radius *SC*, then it is impossible to measure that angle, for the wires cannot be brought to coincide with the lines by which it is contained. Nay, when the chord of the angle does exceed the distance between the nearest extremities, the position of the wires which can be brought into coincidence with the lines is so small as to lead to very serious errors in the result.

The new position micrometer which we propose to substitute for this instrument is free from the defects just noticed, and is founded on a beautiful property of the circle. If any two chords, *AB*, *CD*, fig. 12, intersect each other in the point *O* within the circle, the angle which they form at *O* will be equal to half the sum of the arches *AC*, *BD*; but if these chords do not intersect each other within the circle, but tend to any point *O* without the circle, when they would intersect each other if continued, as in fig. 13, then the angle which they form is equal to half the difference of the arches *AC*, *BD*; that is, calling ϕ the angle required, we have, in the first case, as shown in fig. 12,

$$\phi = \frac{AC + BD}{2};$$

and in the second case, as shown in fig.

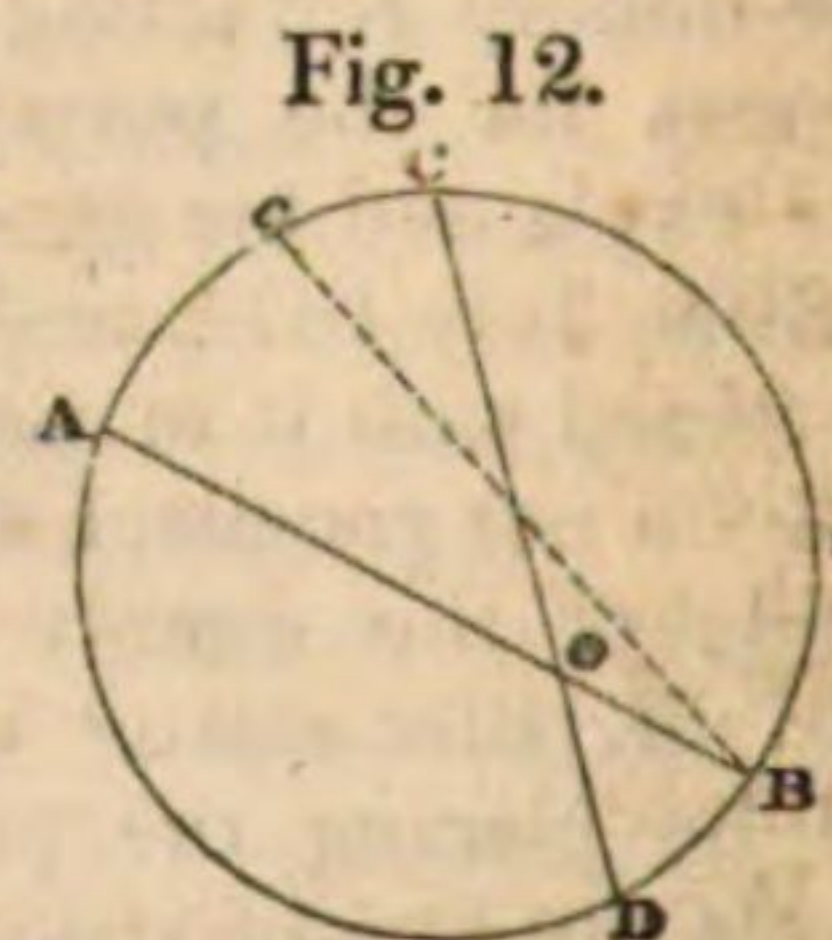


Fig. 12.

¹ Introd. Pract. Astron. vol. ii. p. 233.

² In the case of the double star *Castor*, this revolution is performed in 342 years.

³ Phil. Trans. 1781, p. 509.

Position Micrometers. 13, $\phi = \frac{AC - BD}{2}$. Hence, if the two wires AB, CD be placed in the focus of the first eye-glass of a telescope, the moveable one AB may be made to form every possible angle with the fixed one CD, and that angle may be readily found from the arches AB, CD.

The mechanism for measuring these arches is shown in Plate CCCLVIII. fig. 17, where the graduated circular head CD may be divided only into 180° , in order to save the trouble of halving the sum or the difference of the arches AC, BD; but as it would still be necessary to measure two arches before the angle could be ascertained, we have adopted another method, remarkable for its simplicity, and giving no more trouble than if the wires always intersected each other in the centre of the field.

Let AB, for example, fig. 13, be the fixed wire, and CD the moveable one, and let it be required to find at one observation the angle AOC or ϕ . Set the index of the vernier to zero when D coincides with B; and as C will be at c when D is at B, the arch cA will be a constant quantity, which we shall call b . Making $AC = m$, and $BD = n$, we

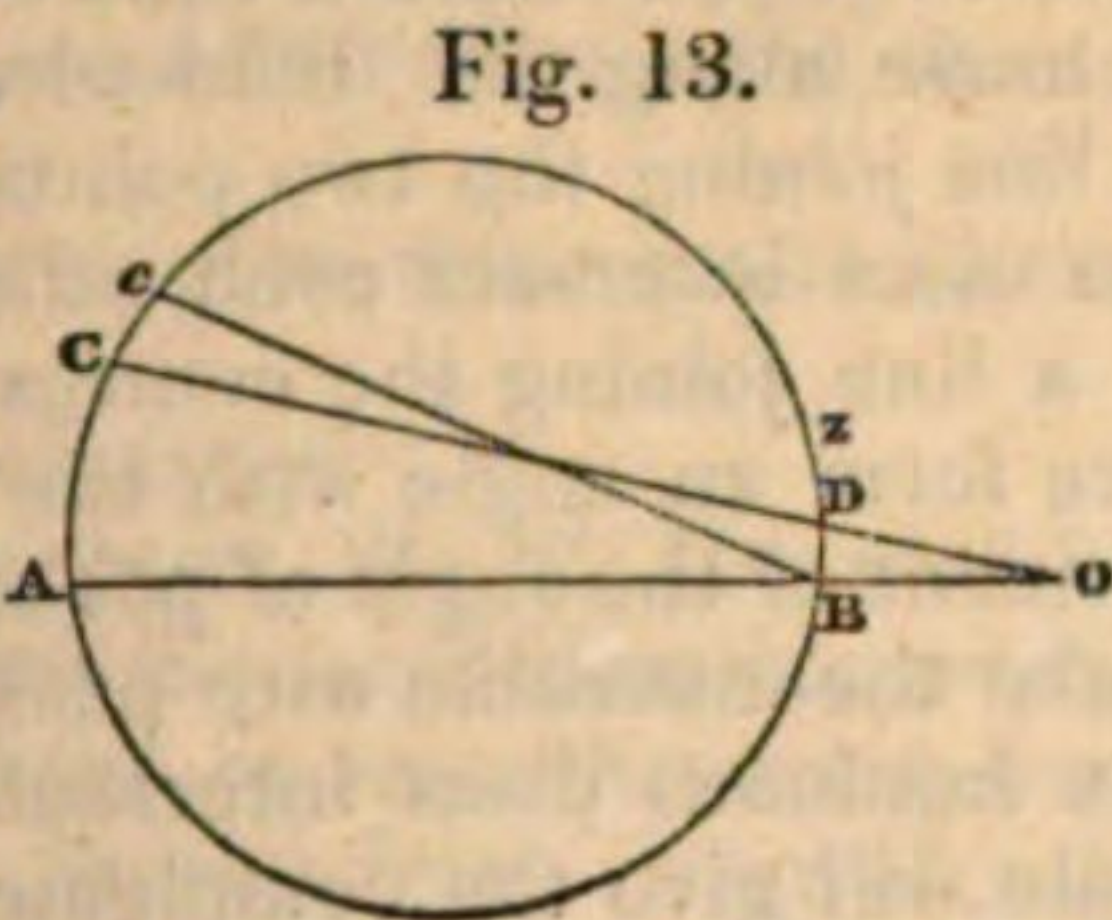


Fig. 13.

have $\phi = \frac{m + n}{2}$. But since the extremity C will move over the space Cc while D describes the space DB, these arches must be equal, consequently $b = m - n$; hence, adding $2n$ to each side of the equation, we obtain $b + 2n = m + n$, or $\frac{1}{2} b + n = \frac{m + n}{2}$, consequently $\phi = \frac{1}{2} b + n$. Hence the angle AOC is equal to half the arch Ac added to the arch DB; or, since Ac is invariable, the half of it is a constant quantity, and the angle required is equal to the sum of this constant quantity and the arch DB.

When the wires do not intersect each other, as in fig. 13, we have $\phi = \frac{m - n}{2}$, and $b = m + n$; hence, subtracting $2n$ from each side of the equation, we have $b - 2n = m - n$, and, dividing by 2, we have $\frac{1}{2} b - n = \frac{m - n}{2}$, consequently $\phi = \frac{1}{2} b - n$. That is, the angle AOC is equal to the difference between half the arch Ac and the arch DB, or to a constant quantity diminished by the arch DB.

In finding the angle AOC, therefore, we have merely to observe the place of the index when the wires are in their proper position; and as the scale commences at B, or where D and B coincide, and is numbered both ways from B, the degree pointed out on the circular head CD, when increased or diminished by the constant quantity, will give the angle of the wires which is sought. The semicircle on each side of a diameter drawn through B is divided into 180° , the 180^th degree being at the opposite end of that diameter.

We may simplify still further the method of reading off the angle AOC, so as to save the trouble even of recollecting the constant quantity, and of adding it to, or subtracting it from, the arch pointed out by the index of the vernier. This advantage is obtained by making the index of the vernier point to the constant quantity upon the part of the scale below B, fig. 12, when the points D, B coincide, or when the wire CD is in the dotted position cB; for it is obvious that if z marks the zero of the scale, and Bz is equal to the constant quantity, the arch Dz, which is pointed out by the index of the vernier, will be equal to $\frac{1}{2} b + n$, or the angle AOC. In like manner, in fig. 13,

where the wires do not cross each other within the field, and where Bz is the constant quantity, the arch Dz marked out by the index of the vernier is obviously equal to $\frac{1}{2} b - n$, or the angle AOC, which the wires tend to form at O. By means of this adjustment, therefore, we are able to read off the angle AOC with the same facility as if the wires intersected each other in the centre of the field, when the arches are accurate measures of the angles at the centre.

The end of the eye-tube is represented in Plate CCCLVIII. fig. 17, where the circular head CD is divided into 360° , and subdivided by the vernier V. L is the level, and AB the part of the eye-piece which contains the diaphragm, with the fixed and moveable wires. The head CD, and the level L, are firmly fixed to the eye-tube T; and from the head CD there rises an annular shoulder, concentric with the tube, and containing the diaphragm, across which the fixed wire is stretched. This diaphragm, which is represented in fig. 18, with the wire extended across, projects through the circle of brass EF. All these parts remain immovable, while the outer tube AB, and the other half EF, of the circular head which contains the vernier V, have a rotatory motion upon the shoulder, which rises from CD. The tube AB is merely an outer case, to protect a little tube within it, which contains the eye-glass, and the moveable diaphragm, with its wire extended across it. The enclosed tube is screwed into the ring EF, and the outer tube is also screwed upon the same ring, so that by moving AB, a motion of rotation is communicated to the vernier V, and to the diaphragm and wire belonging to the inner tube, while the rest of the eye-piece, containing the other diaphragm with its wire, remains stationary. By these means the moveable wire is made to form every possible angle with the fixed wire, and the angle is determined by the method which we have already explained. The fixed wire is placed a good deal out of the centre of the diaphragm to which it belongs; and the diaphragm itself is placed in a cell, in which it can be turned round so as to adjust the wire to a horizontal line when the level is set. The moveable wire is likewise placed at a distance from the centre of its diaphragm, as shown in Plate CCCLVIII. fig. 19; but, by means of screws which pass through the inner tube into the edge of this diaphragm, it can be moved in a plane at right angles to the axis of the eye-piece, so that the moveable wire may be placed either in the centre of the field or at different distances from it.

The double-image micrometer affords a convenient method of measuring angles of position; and we believe this application of it was first made by Sir David Brewster.

In every instrument in which a double image of an object is formed by means of two semi-lenses with their centres at a distance, the one image appears to have a rotatory motion round the other when the telescope is turned about its axis. Thus, in Plate CCCLVIII. fig. 20, if A, B be images of two objects formed by the upper semi-lens when the common diameter of the semi-lenses is perpendicular to the horizon, and C, D the images of the same objects formed by the lower semi-lens; then, by turning the telescope about its axis, or the semi-lenses round in their tube, the image A will appear to move round C in the circle AaE, and the image B round D in the circle BbF, or in the opposite direction if the telescope, or the semi-lenses, are turned the other way. When the distance AC is equal to CD, as in fig. 21, the image A will pass over the image D; or if the telescope is turned in the opposite direction, the image B will pass over the image C. In like manner, when AC is greater or less than CD, the images will move as we have represented them in fig. 20 and 22. In all these cases the four images may be brought into one straight line; and when this takes place,

Position Micrometers.

Double-image micrometer a position micrometer.

Position
Micrometers.

the line which passes through all the images will uniformly form the same angle with the horizon, as the common diameter of the semi-lenses. It is very easy to ascertain with the utmost accuracy when the images form one straight line; but particularly in the case where AC, fig. 21, is equal to CD, for the image of A will then pass over D; and the coincidence of the images will mark the instant when the line which joins them is parallel to the common diameter of the lenses. Hence, as we obtain by this means the relation of the line joining the images to a fixed line in the instrument, the relation of this line to the horizon may be easily found by means of a level, and a divided circular head. If the image is a straight line (fig. 22), then the coincidence of the two images, so as to form one straight line, will indicate the parallelism of that line to the diameter of the semi-lenses.

In constructing a micrometer of this kind solely for the purpose of measuring angles when the eye is not at their vertex, either the object-glass or the third eye-glass might be made the divided lens. If the object-glass is divided, it should be so constructed that it may have a rotatory motion in its cell, by applying the hand to a milled circumference AB, Plate CCCLVIII. fig. 23. Connected with the tube TT of the telescope is a circular ring of brass CD divided into 360° ; and the divisions upon this scale are pointed out by the index of a vernier *v*, which moves along with the semi-lenses. A level L is fixed to the plate AB, having its axis parallel to the common diameter of the lenses, and being adjusted to a horizontal line when the index points to the zero of the scale. In using the instrument, therefore, the observer turns round the semi-lenses by means of the projecting milled circumference AB, till the coincidence of the two images is distinctly perceived. The index of the vernier will then point out upon the graduated head the inclination of the line which is required.

When the telescope is long, this form of the instrument, though extremely simple, is not very convenient. The construction represented in Plate CCCLVIII. fig. 24, is in general to be preferred. This instrument consists of three tubes BL, LC, CA. At the extremity B of the first tube is placed the divided object-glass, and at the other extremity L is fixed the divided circular head EF. The tube CL, which remains always at rest, is fixed to the stand HI by means of the clasp and screw at H. The tube AC, which contains an eye-piece, moves within both the tubes CL and LB. The tube BL extends towards C within the tube CL, and round its circumference are cut a number of teeth, in which the endless screw G works, and thus gives a rotatory motion to the tube LB and the divided head EF. By this means the common diameter of the semi-lenses at B is made to form every possible angle with a horizontal line, which is indicated by a level above L, having its axis parallel to the common diameter of the semi-lenses. The index of the vernier *v*, fixed to the stationary tube CL, points out on the graduated head the angle required. When the instrument is constructed so that the semi-lenses are in the eye-piece, the graduated head must be placed in the eye-tube.

If the principle of this micrometer is applied to the double-image micrometer described in Chap. IV. in which a pair of fixed semi-lenses moves between the object-glass and its principal focus, we obtain an instrument which will measure at the same observation the angle subtended at the eye of the observer by a line joining two points, and likewise the angle which that line forms with the horizon or any other line. When the two images of the line which joins the two points are brought into contact by the motion of the semi-lenses along the axis of the tube, these

images must necessarily be in the same straight line, so that the relation of that line to the horizon, or to any other given line, and the contact of the two images of it which determines its angular magnitude, are obtained simultaneously, without any additional observation or adjustment.

Dr Pearson has given some very useful details respecting the use of double-image micrometers in measuring angles of position.¹

When the brightness of the two stars which compose a double star is considerable, their discs may be drawn out into lines of light either by cylindrical refraction or reflection, and the coincidence of these lines will furnish the means of determining the angle of position.

A position micrometer upon a new principle has been proposed by Sir David Brewster. He expands the images of the two stars into luminous discs till they overlap each other. The southern limb of the lower disc is then made to move along the fixed wire of the position micrometer. A line joining the two points where the circumferences of the discs intersect each other, is obviously perpendicular to a line joining the centres of the stars, and will therefore form an angle with the fixed wire equal to the complement of the angle of position required. If we therefore make the moveable wire pass through the two points where the luminous discs intersect each other, the micrometer scale will give the complement of the angle of position.²

CHAP. VII.—DESCRIPTION OF THE LAMP MICROMETER AND THE LUCID-DISC MICROMETER.

In measuring the distances and angle of position of double stars, Sir William Herschel encountered many practical difficulties which interfered with the accuracy of his results. The uncertainty of the real zero of his scale, the inflexion of light, the imperfections of the screws and divided bars and pinions, and the difficulty of obtaining fibres sufficiently minute for his purpose, but, above all, the disappearance of small stars by the illumination of the wire, led this eminent astronomer to the contrivance of his *lamp micrometer*, which, while it is exempt from these sources of error, has also the advantage of a large scale.

The lamp micrometer is represented in Plate CCCLVIII. fig. 25, where AB is the upright part of the stand, 9 feet high, upon which a wooden semicircle *ghogg*, 14 inches radius, may be fixed at different heights, by a peg *p* put into holes in the stand. An arm L, 30 inches long, moves round a pivot in the centre of the board by means of the handle P, which works by a string *eqho* fastened to a hook at the back of L. The arm L is kept at any inclination to the horizon by the weight of the handle P, which is 10 feet long. A small slider *b*, about 3 inches long, moves along the front of L towards and from the centre at *n*, by means of the handle *rD*, which operates by a string passing over the pulley *m*, and returning by *n* to a barrel at *r*, while a second string *bnw*, with a weight *w*, causes the slider *b* to return to the centre. The end of the arm L is shown on a large scale in fig. 26.

Two lamps *a*, *b*, figs. 27 and 28, $1\frac{1}{2}$ inch high and $1\frac{3}{4}$ inch deep, having sliding doors with small apertures made with a fine needle opposite the flame of a single cotton-thread wick, so that when the sliders are shut down, nothing is seen but two fine lucid points like stars of the third or fourth magnitude. The lamp *a* is placed at the centre *u*, so that its lucid point may occupy that centre, while *b* is hung on the slider S, so that its lucid point may be in a line with the lucid point of *a* when the arm L has a horizontal position.

A person, therefore, at a distance of ten feet, may govern

¹ Introd. to Practical Astron. vol. ii. p. 255.

² Treatise on New Philosophical Instruments, p. 45.

Lamp and
Lucid-Disc
Micrometers.

Fixed Micrometers. the two lucid points so as to bring them into any required position by the handle P; and by the handle D he may place them at any distance, from six tenths of an inch to twenty-five inches.

In using this micrometer, Sir W. Herschel placed it ten feet from his left eye, while with his right he viewed a double star through his Newtonian reflector. By means of his left eye the double star is seen projected upon the micrometer, and he then placed his two lucid points at such a distance that they were exactly covered by the stars. The distance of the lucid points was the tangent of the magnified angles subtended by the stars to a radius of ten feet. This angle, therefore, being divided by the magnifying power of the telescope, gives the real angular distance of the centres of a double star. With a power of 460 the scale was a quarter of an inch for every second. Sir W. Herschel, in measuring the apparent diameter of α *Lyrae* with this instrument, used a magnifying power of 6450. The magnified angle was $38' 10''$, so that the real

angle was $\frac{38' 10''}{6450} = 0''.355$, giving on this occasion a scale

of no less than $8\frac{1}{2}$ inches to a second.¹

Lucid-disc micrometer.

In using high magnifying powers, Sir W. Herschel employed another apparatus called the lucid-disc micrometer. A lucid disc made of oiled paper, or any other semi-transparent substance, was placed in the front slider of a lantern, and illuminated by a flame behind it. The lantern was then removed to a distance till the diameter of the disc appeared equal to that of a planet seen in the telescope, so that the angular diameter of the planet became known by dividing the angle subtended by the disc by the magnifying power of the telescope. The result was affected by the colour of the disc and the degree of illumination. The measure was always too small when the illumination was strong, and too great when a black disc was placed on an illuminated ground. Hence Sir William Herschel took a mean of the two as the true measure.

M. Schroeter of Lilienthal, in measuring the diameters of the four new planets, used a lucid-disc micrometer, which we presume was not much different from Sir W. Herschel's.

Dr Pearson constructed and used an analogous instrument, in which the left eye looked into a tube containing a system of lines upon a disc of glass, or a spider's line micrometer, so that the object seen with the right eye was projected against these divisions, and its angular diameter ascertained.²

CHAP. VIII.—DESCRIPTION OF FIXED MICROMETERS WITH AN INVARIABLE SCALE.

Huygens's micrometer.

The earliest fixed micrometer of which we have a distinct account is that of Huygens, who placed a circular diaphragm in the focus of the eye-glass of his telescope, and found its angular value to be seventeen and a quarter minutes by the time which a star took to pass across it. He then formed two or three long brass plates of different breadths so as to form wedges of different angles. In measuring the diameter of a planet with one of these, he made one of them slide through two slits in the opposite sides of the tube, so that the plane of the brass wedges touched the plane of the circular diaphragm; and having observed in what part of the wedge its breadth just covered the whole planet, he took this breadth in a pair of compasses, and having found what part it was of the whole aperture, he divided seventeen and a quarter minutes by this part, and obtained the diameter required. Sir Isaac

Newton has stated, that the measures thus taken are always in excess. Had Huygens used long wedge-shaped slits or openings, he would by the same process have obtained measures which erred in defect, and the mean between these two measures would have given the true diameter of the planet.

The *reticulum* or fixed micrometer, composed of wires, was invented and used by Cassini. It is shown in the annexed figure, where *ab*, *cd*, *ef*, *gh*, are four hairs or wires intersecting each other at right angles at *i*, in the focus of the eye-glass, *ab*, *cd* being inclined 45° to *ef* and *gh*. In order to find with this apparatus the differences of the right ascension and declination of two stars, direct the telescope so that the first or *preceding* star may appear upon the wire *ab*, and turn round the tube till that star moves along *ab*. The time when this star reaches *i* is carefully noted, and also the time when the *following* star reaches the wire *ed*. The interval between these times, converted into degrees, is the difference of right ascension required. To find the difference of their declinations, mark the time of the second or *following* star's arrival at the points *k* and *l* of the oblique wires *ef*, *gh*. The half of the interval between these times is the time in which the star describes the space *lm* or *mk*, which, converted into degrees *a*, is the angular distance *lm*, which, multiplied by the cosine of the declination of the known or preceding star, gives an approximate difference, which, when applied to the declination of the known star, gives the approximate declination of the unknown or following star. If we now multiply the angular value of *lm* by the cosine of this approximate declination, we shall have the correct difference of declination, which, applied to the declination of the known star, will give the true declination of the unknown star.

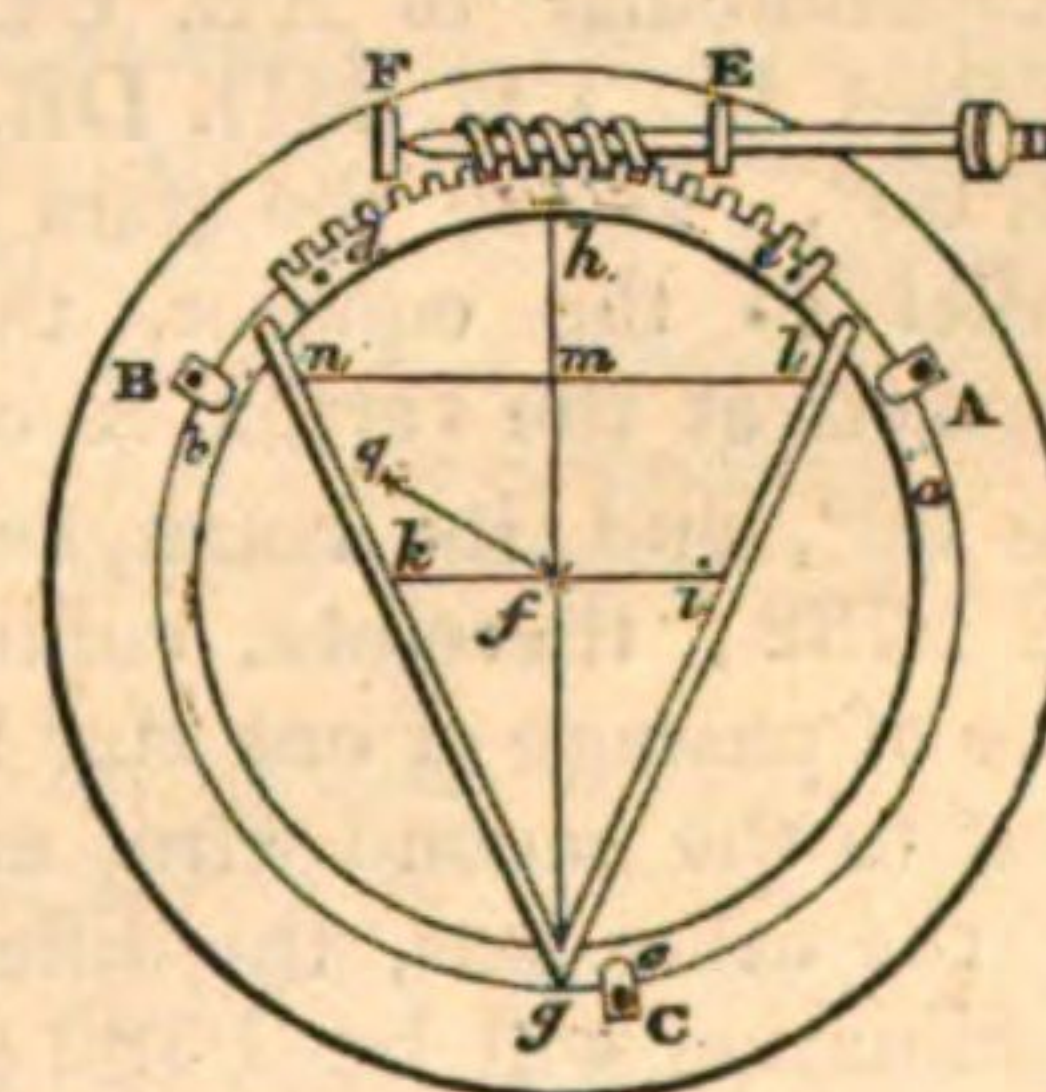
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In using the above reticulum, Dr Bradley found his observations embarrassed by the crossing of all the wires at *i*, which hid the preceding star at the very point where it was required to be most distinctly seen. He therefore proposed the construction shown in the annexed figure, where the wires *hg*, *ki*, intersect one another perpendicularly at *f*, the centre of the rings. Two slender bars of brass *pg*, *og* are fixed to the ring *abc*, and inclined each to the diameter *hg* $26^\circ 34'$, half the angle of a rhomb whose greater diagonal is double of the lesser. Hence *fk* and *fi* will be each one half of *fg*, *ki* = *fg*, and *fm* = *nl* — *ik*. To avoid the inconvenience of turning the telescope about its axis, Dr Bradley placed the ring *abc*, which carries the wires or brass bars in a groove in the fixed ring ABC, and, confining it laterally by three pieces of brass at A, B, and C, he employed an endless screw DEF to work in a toothed rack *de*, fixed to the inner ring *abc*. Let us now suppose the telescope so directed that a star is at *f*, and moving in any line *fg*; then, by turning the milled head D, the wire *fk* will move round *f* till it touches the star at *g*, and will then lie in the direction of the star's motion, while all other stars will move parallel to it. The mode of obtaining accurate results from this apparatus will be un-

Bradley's reticle.

Fig. 15.



Dr Bradley placed the ring *abc*, which carries the wires or brass bars in a groove in the fixed ring ABC, and, confining it laterally by three pieces of brass at A, B, and C, he employed an endless screw DEF to work in a toothed rack *de*, fixed to the inner ring *abc*. Let us now suppose the telescope so directed that a star is at *f*, and moving in any line *fg*; then, by turning the milled head D, the wire *fk* will move round *f* till it touches the star at *g*, and will then lie in the direction of the star's motion, while all other stars will move parallel to it. The mode of obtaining accurate results from this apparatus will be un-

¹ Phil. Trans. vol. lxxii. p. 102.

² Introd. Pract. Astron. vol. ii. p. 245.

Fixed Mi-derstood from the following description of an analogous crometers. contrivance described by Lacaille.

Lacaille's reticle.

This eminent astronomer used a rhomb FMIL, the diagonals of which, FI, ML, must be exactly perpendicular to one another, and as two to one. The length F was 15.4 lines, the angle subtended by ML $1^{\circ} 25' 5''$, and consequently FI $2^{\circ} 50' 10''$, as determined by the passage of several of the equatorial stars. Now, as the vertical height of each triangle in the rhomb is equal to the short diagonal, the path of any star passing through the field in a line parallel to that diagonal will always cut off a similar triangle, and the distance of this path from the common apex will have the same ratio to the vertical height of the large triangle, one half FI, or ML, that the value of the diagonal in time has to the observed time of the passage. Hence the time which any star takes to pass from m to l , reduced to degrees, and multiplied by the cosine of the declination, is the difference of declination required. The difference of right ascension is obtained as before. With this simple apparatus, Lacaille observed the comparative right ascensions and declinations of the 1942 stars which are given in his *Cœlum Australe Stelliferum*. Lacaille constructed another reticulum, in which ML was one fourth of FI.

Rev. Mr Wollaston's reticle.

Mr Wollaston employed a reticulum similar to that shown in the annexed figure, AB being the horary line, and CD the equatorial line. The four squares being within the field, any of them may be used separately, so that observations made successively in a pair of them will check each other as well as the principal observation made in the large right-angled triangle. As the diagonals are equal to one another, they afford a larger passage of a star, and thus increase the accuracy of the observation.

M. Valz's reticle.

M. Valz¹ of Nismes has proposed the reticulum shown in fig. 18, as possessing several advantages over others. It consists of three wires AB, CD, AD, and the equatorial one MN perpendicular to AB, CD. The arches AC, CM, MD, DB, &c. are all 60° . When the stars pass parallel to the equator, the angle formed at the vertex A or B will be 30° , and its cotangent $= \sqrt{3} = 1.732$; therefore, calling t the line of passage of one star from the first to the second wire, and t' that of the other star, the difference of declination will be $1.732 (\pm t \mp t')$, and the difference of right ascension will be had from the times of the stars passing the middle of the space between CD and AB, or the means of the times of passing CD and AB. Baron Zach observes, that this reticulum requires no illumination, that the values of its lines do not require to be known, and that it may be used out of exact adjustment to the parallel of declination, as the corrections for such want of adjustment are easily computed.

Fraunhofer's net-micrometer.

The fixed net-micrometer of Fraunhofer is shown in Plate CCCLVIII. fig. 29. The vertical and oblique lines shown in the figure are cut upon glass with fluoric acid or dia-

mond, and the plate has a circular motion in its cell. These Fixed Mi. lines are illuminated by light passing through the eye-tube crometers. and falling on their cut edges, so that no light passes down the tube. The lines parallel to ef are adjusted perpendicular to a circle of declination, and in that position the oblique light of the lamp illuminates both the vertical and inclined lines. The mutual distances both of the vertical and inclined lines are known from the machine by which they were drawn, and hence the ratio of the times of transit of a star from the vertical to the inclined lines will enable us to determine the position of these in reference to a circle of declination. "The great number of lines," says Dr Pearson, "afford the means of making several observations, which, on an average, will give right ascensions and declinations equally exact, whether the differences of declination be great or small. When the difference of right ascension is small, as in the case of double stars, the transit of both stars cannot well be observed over the same individual line, but one of them may be observed at the first, and the other at the second line, alternately, till the observer is satisfied with his observation; and should the network experience an alteration of position from any cause, it will in all probability be detected before the computation is commenced. The ingenious artist contrived an engine by which he could cut straight parallel lines at distances so small as $\frac{1}{10000}$ of units from each other, and to be crossed by other parallel lines at any given angle of declination; and in the net-micrometer he formed the parallel lines at such a distance from each other that the inclined intervals bear the same proportion to the vertical intervals that the cosine of the angle of inclination bears to radius, so that about as many transits will take place over the inclined as over the vertical lines. Five lines only are drawn at equal distances from each other, and the sixth line, including the fifth interval, is cut at the distance of one interstice and a half; yet the whole value of any number of intervals may always be known, provided it be noticed how many of the larger kind are included in the whole number. When the cell containing the disc is attached to a revolving graduated circle, the position of a line uniting two stars may also be measured, by first adjusting zero to the equatorial position of the line fg , and then turning the divided disc round till all its parallels successively receive both the stars at the same instant as they pass through the field, which contemporary ingresses may be effected by repeated adjustments and subsequent trials, when the telescope is mounted on an equatorial stand properly rectified.²

Another micrometer of Fraunhofer's is shown in Plate CCCLVIII. fig. 30, and consists of concentric circles cut upon glass, and illuminated like the preceding one. The inner and smallest circle is like a dot. Other five circles are seen in a telescope of five feet focal length, magnifying 110 times. With a power of 63, eight circles are visible; and with the lowest power of 45, eleven circular lines are visible. The observer may choose any circle he likes for observing the passage of the star, avoiding those in which it would pass near the centre or near the circumference. The observation, too, may be made with more rings than one. The following are the dimensions of the circles in one of these instruments.

Diameter in Paris Inches.		Diameter in Paris Inches.	
Circle 1.	.0038	Circle 7.	.4426
2.	.0243	8.	.5264
3.	.0840	9.	.6338
4.	.1678	10.	.7178
5.	.2513	11.	.8012
6.	.3590		

¹ Zach's *Correspondance Astronomique*, tom. i. p. 353.

² *Introd. Pract. Astron.* vol. ii. p. 143.

Micrometers for Microscopes.

Fraunhofer's suspended circular micrometer.

By subtracting these numbers from one another, we obtain the breadths of the spaces between the rings.

Fraunhofer's suspended annular micrometer, which is a more perfect instrument than the preceding, is shown in Plate CCCLVIII. fig. 31, which represents a disc of glass, having a hole in its centre a little larger than the inner diameter of a metallic ring *oo*, turned truly in a lathe. This ring is cemented on the glass disc, and when placed in the field of view of a telescope, the observer notes the instants when a star on the limb of a planet enters and emerges from each side of the ring. The only data required for computing the difference of right ascension and declination, are the times that an equatorial star takes to pass along the internal and external diameters of the ring. The passage of stars whose relative position is required, must be observed at a distance from the centre, as well as from the upper edge of the ring. The formulæ of Bessel for using this and other circular micrometers will be found in Zach's *Monatliche Correspondenz*, vol. xvii. xxiv. and xxvi.

Cavallo's mother-of-pearl micrometer.

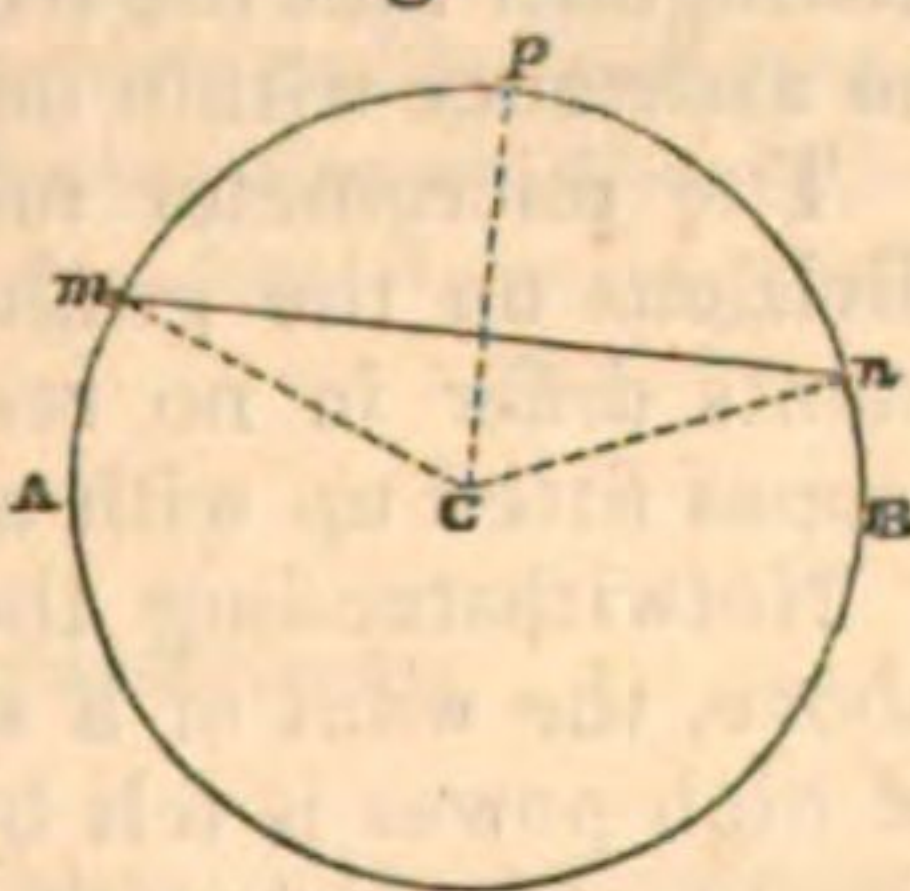
A simple and useful fixed micrometer, proposed by Mr Cavallo, is a divided slip of thin mother-of-pearl stretching across the diaphragm of the telescope, and finely divided into 200ths of an inch. It is shown in Plate CCCLVIII. fig. 32, crossing the diaphragm of the telescope. The value of the division may be ascertained either by measuring a bar, or by the passage of an equatorial star across the field of view.

In a portable telescope this micrometer is very convenient, though it has the great disadvantage of shutting out the field of view. In telescopes upon stands it will measure only angles in one direction, unless there is a contrivance to turn it round. This micrometer has also the additional imperfection, that its divisions, from being unequally distant from the eye-glass, are not all seen with the same distinctness.

Circular mother-of-pearl micrometer.

To remove these imperfections, Sir David Brewster proposed, in 1805, the circular mother-of-pearl micrometer, which is shown in Plate CCCLVIII. fig. 33, where the black ring which forms part of the figure is the diaphragm of the telescope, and the more luminous part is an annular portion of mother-of-pearl divided on its inner circumference into 360°. This divided circumference can be placed exactly in the focus of the eye-glass, and all its parts seen with perfect distinctness. In order to understand the use of the instrument, let *ApB* be the inner edge of the mother-of-pearl ring, and *mn* the object to be measured. Bisect the arch *mn* in *p*, and draw *Cm*, *Cp*, *Cn*, and we shall have $AB : mn = \text{rad.} : \sin. \frac{mpn}{2}$, and $mpn = \sin. \frac{\frac{1}{2} mpn}{\text{rad.}} \times AB$, a formula by which the angle subtended by the chord of any number of degrees may be readily found. The first part of the formula is constant, while *AB* varies with the magnifying power employed.

Fig. 19.



CHAP. IX.—DESCRIPTION OF MICROMETERS FOR MICROSCOPES.

Micrometers for Microscopes.

All the micrometers above described may be adapted to compound microscopes, where the eye-glass has a considerable focal length. A good micrometer, however, for sin-

gle microscopes, which can be used with facility, and at the same time give accurate results, is still a desideratum. When the single lens is so minute, or when the first lens of a microscopic doublet or triplet almost touches the surface of the object, it is an extremely difficult matter to introduce any scale, or any minute body of known dimensions, with which the object may be compared. In some cases, when the object to be measured is minute, the seed of the *lycoperdon bovista* or puff-ball might be introduced, its diameter being about the $\frac{1}{8500}$ th part of an inch; and when the object is less minute, the seed of *lycopodium* may be used, its diameter being $\frac{1}{940}$ th of an inch. We may advantageously adopt, in some cases, the method of Dr Jurin,¹ who introduced into the field small pieces of silver or brass wire, whose diameter he had previously ascertained by coiling the wire round a cylinder, and observing how many breadths of the wire were contained in a given number of inches.

This method of introducing a substance of known dimensions may be carried much farther. We may use all the variety of hairs and wool which have a known diameter; and for this purpose Dr Young's tables of substances measured by the eriometer will be of great use. The following are a few of them:

Diameter in Parts of an Inch.

Lycoperdon bovista, seed of.....	8500th of an inch.
Smut of barley.....	4600th ditto.
Silk, fibre of (average).....	2500th ditto.
Human blood, particles of (<i>Bauer</i>).....	2500th ² ditto.
Mole's fur.....	1875th ditto.
Goat's wool.....	1575th ditto.
Saxon wool.....	1320th ditto.
Farina of Laurestinus.....	1100th ditto.
Seed of lycopodium.....	940th ditto.

The distance of the fibres of the crystalline lens of fishes may also be advantageously used, and also the distance of the teeth which unite the fibres. For this purpose, the lens must be well dried, and perfectly hard, so that with a sharp knife we can detach minute portions of any of the laminae. The thinnest should be used; and as the fibres always taper to the pole, and the teeth become smaller in proportion as the fibres diminish, we must determine the distance of the fibres, and also those of the teeth, at both ends of the laminae, by the method described by Sir David Brewster in the *Philosophical Transactions* for 1833, p. 324. The larger lined scales of moths and butterflies may also be used, especially as we can measure the distance of the lines by the coloured spectra which these lines produce.³ These operations will require much dexterity on the part of the observer, and they are recommended only to those who cannot succeed in their measurements by other methods.

An excellent method of measuring microscopic objects is to project the image of the object against a divided scale, at a given distance from the eye. The scale must be seen either by the same eye which is looking into the microscope, or by the other eye. In the first case, the rays from the microscope will enter one side of the pupil, and the rays from the divided scale the other side; the aperture through which we look at the scale, and the aperture of the microscope, being at a distance less than the diameter of the pupil. When the right eye looks at the divided scale, the left, which looks into the microscope, will see the object projected against the scale, although it has no vision of the scale itself. This second method may be carried into effect in two ways. The scale may form no part

¹ Physico-Mathematical Dissertations, p. 45.

² We consider this the best measure.
³ The late Mr Pond has observed, that the pale, slender, double-headed scales of the *Pontia* or *Pieris brassica*, which taper to a point, and terminate in a brush-like appendage, are of an invariable length, about $\frac{1}{16}$ th of an inch.

Micrometers for Microscopes.

Dr Wollaston's lens-micrometer.

of the instrument, and may be viewed by the naked eye; or it may form part of the instrument, like a binocular telescope, the left eye looking into one tube, viz. the microscope, while the right eye looks into another tube, in which a divided scale is magnified by an eye-lens.

Dr Wollaston has constructed and used a very ingenious micrometer on the first of the principles above mentioned, viz. when the object and the scale are viewed by the same eye; but its use is limited to microscopes with small lenses. When the lenses are larger, we have adopted another method, namely, to perforate the lens with a small hole in or near the centre, or, if it is thought better, near the margin of the lens. A slit extending from the margin of the lens may often be executed more easily.

The following is Dr Wollaston's own description of this instrument:

"This instrument," says Dr Wollaston, "is furnished with a single lens of about $\frac{1}{12}$ th of an inch focal length. The aperture of each lens is necessarily small, so that when it is mounted on a plate of brass, a small perforation can be made by the side of it in the brass, as near to its centre as $\frac{1}{3}$ th of an inch.

"When a lens thus mounted is placed before the eye for the purpose of examining any small object, the pupil is of sufficient magnitude for seeing distant objects at the same time through the adjacent perforation, so that the apparent dimensions of the magnified image might be compared with a scale of inches, feet, and yards, according to the distance at which it might be convenient to place it.

"A scale of smaller dimensions, attached to the instrument, will, however, be found preferable, on account of the steadiness with which the comparison may be made; and it may be seen with sufficient distinctness by the naked eye, without any effort of nice adaptation, by reason of the smallness of the hole through which it is viewed.

"The construction that I have chosen for the scale is represented in Plate CCCLVIII. fig. 33. It is composed of small wires about $\frac{1}{30}$ th of an inch in diameter, placed side by side so as to form a scale of equal parts, which may be with ease counted by means of a certain regular variation of the lengths of the wires.

"The external appearance of the whole instrument is that of a common telescope consisting of three tubes. The scale occupies the place of the object-glass, and the little lens is situated at the smaller end, with a pair of plain glasses sliding before it, between which the subject of examination is to be included. This part of the apparatus is shown separately in fig. 35. It has a projection, with a perforation, through which a pin is inserted to connect it with a screw, represented at *b*, fig. 34. This screw gives lateral motion to the object, so as to make it correspond with any particular part of the scale. The lens has also a small motion of adjustment, by means of the cap *c*, fig. 36, which renders the view of the magnified object distinct.

"Before the instrument is completed, it is necessary to determine with precision the indications of the scale, which must be different, according to the distance to which the tube is drawn out. In my instrument, one division of the scale corresponds to $\frac{1}{10000}$ th of an inch when it is at the distance of 16.6 inches from the lens; and since the apparent magnitude in small angles varies in the simple inverse ratio of this distance, each division of the same scale will correspond to $\frac{1}{3000}$ th at the distance of $8\frac{3}{10}$ inches; and the intermediate fractions $\frac{1}{6000}$, $\frac{1}{7000}$, &c. are found by intervals of 1.66 inch, marked on the outside of the tube. The basis on which these indications

were founded in this instrument was a wire, carefully ascertained to be $\frac{1}{200}$ th of an inch in diameter, the magnified image of which occupied fifty divisions of the scale when it was at the distance of 16.6 inches; and hence one division

$$\text{division} = \frac{1}{50 \times 200} = \frac{1}{10000}.$$

Since any error in the original estimate of this wire must pervade all subsequent measures derived from it, the substance employed was pure gold drawn till fifty-two inches in length weighed exactly five grains. If we assume the specific gravity of gold to be 19.36, a cylindrical inch will weigh 3837 grains; and we may hence infer the diameter of such a wire to be $\frac{1}{200}$ th of an inch, more nearly than can be ascertained by any other method.

"For the sake of rendering the scale more accurate, a similar method was, in fact, pursued with several gold wires of different sizes, weighed with equal care; and the subdivisions of the exterior scale were made to correspond with the average of their indications.

"In making use of this micrometer for taking the measure of any object, it would be sufficient, at any one accidental position of the tube, to note the number on the outside as denominator, and to observe the number of divisions and decimal parts which the subject of examination occupies on the interior scale as numerator of a fraction, expressing its dimensions in proportional parts of an inch; but it is preferable to obtain an integer as numerator, by sliding the tube inward or outward, till the image of the wire is seen to correspond with some exact number of divisions, not only for the sake of greater simplicity in the arithmetical computations, but because we can by the eye judge more correctly of actual coincidence than of the comparative magnitudes of adjacent intervals. The smallest quantity which the graduations of this instrument profess to measure, is less than the eye can really appreciate in sliding the tube inward or outward. If, for instance, the object measured be really $\frac{1}{9900}$, it may appear $\frac{1}{10000}$, or $\frac{1}{9800}$, in which case the doubt amounts to $\frac{1}{30}$ th part of the whole quantity. But the difference is here exceedingly small in comparison to the extreme division of other instruments, where the nominal effect of its power is the same.

"A micrometer with a divided eye-glass may profess to measure as far as $\frac{1}{10000}$ of an inch; but the next division is $\frac{2}{10000}$, or $\frac{1}{5000}$; and though the eye may be able to distinguish that the truth lies between the two, it receives no assistance within one-half part of the larger measure."

The micrometer microscopes used for reading off the divisions on the graduated limb of astronomical instruments differ in no respect from the eye-pieces of telescopes fitted up with micrometers.

Notwithstanding the value of the methods described above, the want of a simple micrometer for microscopes of high power is felt by every person who has been practically occupied with this class of researches; and we cannot give a better proof of this than by adducing in support of our opinion the different measures that have been given by able and ingenious observers of the size of the particles of the human blood.

Dr Thomas Young.....	1-6060th part of an inch.
Dr Wollaston.....	1-5000th ditto.
MM. Prevost and Dumas.....	1-4076th ditto.
Captain Kater.....	1-4000th ditto.
M. Ehrenberg ²	1-3600th ditto.
Messrs Hodgkin and Lister.....	1-3000th ditto.

¹ Phil. Trans. 1813, p. 119.

² In measuring the size of the fossil infusorias recently discovered by himself, M. Ehrenberg assumes a globule of human blood to be $\frac{1}{300}$ th of a line in diameter, or $\frac{1}{3600}$ th of an inch, but of what inch is not mentioned. He does not state whether this mea-

Micrometers for Microscopes.

Micro- scope.	Sir David Brewster.....	1-2556th	part of an inch.
	Dr Jurin ¹	1-1940th	ditto.
	Mr Bauer's best observation.....	1-2500th	ditto.
	next best.....	1-2000th	ditto.
	worst observation....	1-1000th	ditto.

The three measures of 1000, 2000, and 2500, have been recently given by Mr Bauer himself, as the different steps which he made towards what he conceives the best measure, viz. 1-2500th, which he obtained repeatedly with an improved achromatic microscope. As Dr Young obtained his measure *erimetrically*, namely, by measuring the diameter of the first red ring produced by looking through the blood at a luminous object, we cannot conceive it possible that he could have committed such a mistake as to make the diameter of that ring nearly *thrice as great* as it should be, according to Mr Bauer's results, or more than thrice as great as the concurring measures obtained by Jurin and Leewenhoeck. The only explanation we can give is, that the particles of the blood must have an organized structure, or consist of portions separated by lines which have the magnitude assigned by Dr Young. In order to submit this explanation to the test of experiment, Sir David Brewster examined the particles of blood a few minutes after it was drawn, when dried by natural

evaporation on a plate of glass. Each particle he found to consist of a dark rim, within which is a bright circle; then a darkish central spot, which spot in some globules may be resolved into a dark ring, a bright ring within this, and then a small central black spot. Here, then, is the cause of Dr Young's mistake. The red ring of light which he measured in the erimeter was not that which was due to the globule as a whole, but to the parts of the globule. Being anxious to obtain more complete evidence of this fact, we placed lycopodium powder beside the globule of blood, and found that the diameter of the globules was to that of the lycopodium seed as 5 to 18. We then compared the diameter of the red ring produced by the seed with the diameter of the red ring produced by division on steel, in which there were 1250 to the inch, as executed for us by the late Sir John Barton, and found the diameter of the seed to be the 697th of an inch. We compared it also with the ring produced by divisions of which there were 625 to the inch, and found its diameter the 717th part of an inch. The mean of these two is the 710th² part of an inch, which, increased in the ratio of 5 to 18, gives the 2556th part of an inch as the measure of the diameter of the globules of blood, agreeing almost exactly with the recent measure of Mr Bauer.

Micro-
scope.

MICROSCOPE.

MICROSCOPE, from *μικρος*, a small object, and *σκοπεω*, to see or examine, is the name of a well-known optical instrument for examining and magnifying minute objects, or the minute parts of large ones. Dr Goring has, in his various ingenious works on the microscope, used the word *engiscope*, from *εγγυς*, near, and *σκοπεω*, to see; but the old and venerable term is so associated with the history of optical discovery, and is so expressive of the application of the instrument, that we cannot consent to the proposed change.

As the early history of the microscope must form a part of the general history of OPTICS, we must refer our readers to that article for an account of its invention and progressive improvements, as well as for an account of the optical principles on which it depends.

There is probably no branch of practical science which has undergone such essential and rapid improvements as that which relates to the microscope. It has become quite a new instrument in modern times, and it promises to be the means of disclosing the structure and laws of matter, and of making as important discoveries in the infinitely minute world, as the telescope has done in that which is infinitely distant.

CHAP. I.—ON SINGLE MICROSCOPES.

On single
micro-
scopes.

A single microscope is one in which only one convex lens is used for magnifying objects. The object to be examined is placed before the lens, in its focus; and the rays which emerge from the lens after refraction are parallel, and therefore give distinct vision of the object to the eye placed behind it. The simplest form of the single microscope is when the lens is fitted into a rim of brass furnished with a handle, and the object being held in the left hand and the lens in the right, it may be examined with great correctness. If the convex lens is very minute, and has a short focal length, such as from the 10th

to the 100th of an inch, it cannot be conveniently used in the hand, and must therefore be placed in a firm microscope stand, having a shelf for holding the object, a screw or a rack and pinion for placing the object in the focus of the lens, and a lens or mirror, or both, for throwing light upon the object. In this form, however complex be its structure, it is still called a single microscope.

A single microscope, in order to have all the perfection which art can give, must consist of a *substance* perfectly homogeneous, like a fluid without double refraction, or any variation of density. Its *figure* ought to be that of a plano-convex lens, whose convex surface is part of a hyperboloid, in order to correct completely the spherical aberration. Its *surface* should be perfectly smooth and highly polished, so as not to disturb the perfection of vision; and the substance of which it is made should have the *lowest dispersive power*. As it is a great object to obtain high magnifying powers with as little convexity as possible, and a large aperture, substances with high refractive and low dispersive ones are the most suitable for single lenses, such as *diamond*, *garnet*, or which have no double refraction when well crystallized; or such as *ruby*, *sapphire*, *topaz*, &c. which have double refraction. As *fluor spar* has the lowest *dispersive power*, it might be used with great advantage when high powers are not wanted, and when the diminution of colour is an object.

Of all the substances we have named, fluids have properties best suited for single microscopes. They possess perfect homogeneity, their surfaces when made into lenses are perfectly smooth, and it is possible to mould minute drops of them into a form approaching to that of the hyperboloid. Their defect, however, consists in their not having a high refractive power, in their want of durability, and the difficulty of forming sufficiently minute lenses for producing high magnifying powers. These defects, however, especially the last, may be overcome by patience and experience; and in proof of this we may state, that we

Materials
for single
micro-
scopes.

sure is taken by himself or not. He reckons the thickness of a human hair at $\frac{1}{8}$ th of a line at its mean thickness, or $\frac{1}{57}$ th of an inch.

¹ This result was confirmed by Leewenhoeck, who used the same wire, which was sent to him by Dr Jurin. Phil. Trans. No. 377.

² Dr Young makes this the 940th of an inch, but he has certainly committed a mistake in his observation.

Single Mi-
croscopes. have succeeded in forming fluid lenses that were fully equal to the best sapphire lenses that have been executed.

In the present state of this branch of science, it would be unprofitable to detail the methods of producing microscopic globules of glass, given by Dr Hooke, Father di Torr  of Naples, Mr Butterfield, or Mr Sivright; because when they are made after their methods, and in the most perfect manner which the methods will permit, they are of no value compared with lenses of glass when ground and polished to the same focal length.¹

We shall therefore proceed to describe a single microscope when fitted up in the best form for observation.

Description of a Single Microscope.

Single mi-
croscope.

The most essential part of this instrument is the lens or lenses, upon which the value of the microscope depends. The lenses are generally made of plate-glass, and should have focal distances varying from the 1-10th to the 1-50th of an inch. In order that the spherical aberration of these lenses may be the smallest possible, the radii of their two surfaces should be as 1 to 6; the surface whose radius is as 1, or the most convex side, must be turned towards the eye. The lenses, thus made, are then set in the centre of the lower surface of concave brass caps, a section of one of which is shown in Plate CCCLIX. fig. 1.

The best mode of fitting up the microscope is that contrived by Mr Pritchard, which is represented in fig. 2, on a scale about one third of its real size. It is shown in an inclined position; but it may be used either in a vertical or a horizontal one, according to the convenience of the observer. The body of the instrument rests on a pillar *b*, supported by three legs, shown at *a*, and is connected with it by the clip *f*, being fixed by the pinching screw *f*. Within the tube *c* there slides a tube *h*, connected by a screw which passes through it to the triangular tube or bar *i*, carrying the arm *ij*, into which is placed the brass cap *j* which carries the lens. This lens is adjusted to the distinct vision of objects placed on the stage *l* by sliding the tube *h* up or down, and a perfect adjustment is obtained by turning the milled head *k*. The stage *l*, which carries the objects, is fitted into the triangular box *r* at the extremity of the stem, by means of two pins, and can be removed at pleasure. The spring slider-holder, for holding the sliders in which the objects are placed, is fixed by a bayonet-joint into the stage; and it may be used to hold stops or diaphragms for limiting the field of view. The tube above *f* represents an illuminator fixed to the slider-holder. Upon the tube *c*, two sockets *d*, *e* slide with sufficient spring and friction to keep them in their place. The socket *d* carries the reflector *d*, and the socket *e* carries the condensing lens, which is not inserted in the figure.

A section of the stem *rch* is shown in fig. 3, in order to exhibit the mechanism by which the adjustment is effected. Into the box *r*, screwed into the top of the stem, is fitted the triangular tube *ii'*, which carries the arm *ij*. In the lower end *i'* of this triangular tube is a small block with a fine screw working in it, the stem of which turns along with the milled head *k*, to which it is fixed. The upper end of a spiral spring, shown in the figure, bears against the block *i'* at the bottom of the triangular tube,

while its lower end acts against a stop fixed within the sliding tube *h*. The method of managing, illuminating, and examining opaque objects with this microscope is the same as that used in the achromatic compound microscope, in the drawing of which it will be more distinctly seen.

The preceding instrument of Mr Pritchard's is intended for general purposes; but as the dissection of botanical and other objects is now a leading object with naturalists, we shall add an account of another microscope, constructed by Mr A. Ross, with much skill, for Mr W. Valentine of Nottingham, the parts of which are given in considerable detail.

A perspective view of this microscope is shown in Plate CCCLIX. fig. 4. It is supported on a closing tripod, *aaa*, whose feet can be folded together, and are made of hard bell-metal, prevented from springing by edge bars, as seen on the left-hand foot. A firm pillar, which rises from the tripod, carries the stage *x*, which is fixed on brackets, to give a steady support to the hands of the operator. A capital, *e*, fixed to the top of the tube by three screws, has in its axis a triangular hole, into which is fitted the triangular tube *f*, the lower end of which passes through another similar triangular tube in the piece *gg*, fixed to the tube. This triangular tube is made to slide up and down by a fixed screw, *i*, which is wrought by a large milled head, *o*, which is most judiciously placed at the base of the pillar. At the top and bottom of the triangular tube, at *g* and near *r*, are fitted two pieces, with triangular holes through them for receiving the triangular bell-metal bar *ss*, which moves up and down in them. This bar carries the arm 10 with the lenses. It is moved up and down, so as to adjust the lenses to distinct vision of the objects on the fixed stage, by the rack and pinion *t*, when a quick adjustment is required; but when a slow and nicer adjustment is wanted, it is effected by the milled head *o*. A slit, *uv*, is made in the shaft of the pillar, to allow the neck of the small milled head *t* to move up and down; for when the screw is in action by the large milled head *o*, the triangular tube and the bar move together. The triangular bar is perforated at both ends, the upper perforation for receiving a conical pin, and the lower for admitting the adjusting screw to preserve the length of the bar. The piece *w* is removed from the side of the pillar, to show the bearings of the pinion *t*, which are attached to the triangular tube. The bar moves $1\frac{1}{2}$ inch, and the tube $1\frac{1}{2}$, so that we can command an elevation of 3 inches. At the ingenious suggestion of Mr Solly, the screw *i*, moved by the milled head *o*, has fifty threads in an inch, and the milled head is graduated into 100 parts, for the purpose of measuring the thickness of any vessel or other object in the direction of the axis of vision. For this purpose the upper surface of the body is brought into distinct vision; the division at which the index or pin of the tripod stands is then observed; and the under surface being in like manner brought into focus by turning the milled head *o*, the division is again observed. The number of divisions, which are each 5000ths of an inch, between these two numbers, will indicate, according to Mr Valentine, the space through which the lens has passed, which is the diameter of a vessel.²

In this microscope, different parts of an object may be brought into the field, either by moving the stage or the

¹ These methods may be found by the following references:—Hooke's *Micrographia*; Di Torr , *Phil. Trans.* 1765, p. 246, 1766, p. 67; Butterfield, *Phil. Trans.* 1678; Sivright, *Edin. Phil. Journal*, 1829, vol. i. p. 81.

² This is not the case, as the refraction of the light issuing from the lower side of the vessel or object is not considered. The right mode is, after having observed the upper surface of an object lying upon glass, remove the object, and observe the divisions when the surface of the glass is seen distinctly: the difference will be the true thickness. Mr Samuel Varley is said to have constructed an instrument on this principle for measuring the thickness of foci of lenses; but unless he removed his lens after observing the first surface, his results must have been all erroneous.

Single Microscopes. lens, a very important requisite in a microscope used for the purposes of discovery. With this view, the large stage x is formed of three plates, the lowest of which is fixed to the pillar by the ring 1; and, to make it bear the weight of the hands, it rests upon the strong brackets 2, 2. The under side of this plate is shown in fig. 6; the middle plate, fig. 7, contains two pair of dovetail slits, 3, 3 and 4, 4, the widest orifice of each being on opposite sides of the plate. The dovetail pieces in 4, 4 screw into the upper side of the upper plate, fig. 8, the points of the screws being shown at 4, 4 in that figure, while the dovetail pieces in 3, 3 are secured to the upper side of the under plate by the screws 3, 3, fig. 3. The plates are thus moved diagonally, and at right angles to one another, by the adjusting screws 7 and 8. One of the screws, with its ball and milled head, is shown in fig. 9. In the adjusting screw 7, the ball is placed in spring couplings, and fastened to the under side of the upper plate. These screws are judiciously placed, one on each side of the pillar, that the hand may reach them easily and not intercept the light. By turning first one screw, and then the other, or both at once, any part of the object may be brought into the field.

The arm for holding the lenses is shown at 10, in fig. 1 and fig. 10. A conical pin projects from underneath, and fits into a hole made down the triangular bar, as shown at 9, fig. 8. The lens will therefore have a circular movement in a horizontal plane, and it may be placed at any point in this plane by the action of the rack and pinion at 10. Hence the most complete adjustment can be obtained without any motion of the stage.

The elevated stage for holding the objects is shown at 11 in fig. 4 and 8. A tube, 12, fig. 11, screws into the upper plate, and upon this fits the tube 11, carrying the finger spring, shown in fig. 4. Objects of different thickness are thus kept down upon the plates by the pins sliding in the small pipes. An elevated stage is shown in fig. 12, for viewing the sides of objects without disturbing them. A condensing lens, fig. 13, slides into the sockets 5 or 6; and fig. 14 shows the pincers, to be applied in the same manner.

The large reflector above a , fig. 8, may be removed, and any other illuminating apparatus substituted. That of Dr Wollaston is shown in fig. 15, at 19. The handles 18, 18 serve to move the lens up and down in the tube.

The mode of attaching the body of a compound microscope is shown in fig. 16. For this purpose the arm 10, fig. 4, is withdrawn, and the conical pin 20 is made to fit in the same hole in the triangular bar.

Mr Valentine informs us, that with this instrument he can dissect under a lens $\frac{1}{20}$ th of an inch focus.

As the stand and apparatus now described may be used along with all single microscopes, and also with what are called doublets and triplets, we shall now proceed to give an account of the various improvements which the single microscope has undergone.

Single Microscopes made of Precious Stones.

Microscopes of gems. The low refractive power of glass rendered it necessary, when high powers were wanted, to use lenses with very short foci, and consequently with very deep curves and very small diameters, so as to admit only a narrow pencil of light into the eye.

Sir David Brewster was the first person who pointed

Single Microscopes. out the value of using other materials for the construction of lenses; and he remarked, that no essential improvement could be expected in the single microscope, unless from the discovery of some transparent substance, which, like the *diamond*, combines a high refractive with a low dispersive power. Having experienced the greatest difficulty in getting a small diamond cut into a prism in London, he did not conceive it practicable to grind and polish a diamond lens,¹ and therefore did not put his opinion to the test of experiment. He got two lenses, however, executed in Edinburgh by Mr Peter Hill, an ingenious optician, the one made of ruby, and the other of garnet; and these lenses he found to be greatly superior to any lenses that he had previously used.

Dr Goring, whose zeal and success in the improvement of microscopes has not been surpassed, directed the attention of Mr Pritchard in 1824 to the passages in Sir David Brewster's Treatise on New Philosophical Instruments, respecting the value of the precious stones for single microscopes; and having immediately seen their full force, it was agreed that they should undertake to grind a diamond into a magnifier.

Diamond Lenses.

The history of this attempt is so interesting, that we must give it in Mr Pritchard's own words:—"For this purpose," says he, "Dr Goring forwarded me a small brilliant diamond to begin upon; and it was proposed to give it the curves that in glass would produce a lens of a twentieth of an inch focus, with the proportion of the radii of their surfaces as *two to five*. This stone I ground with the proper curves, and polished the flatter side, contrary to the expectations of many whose judgment in these matters was thought of much weight, who predicted that the crystalline structure of the diamond would not permit it to receive a spherical figure. When thus far advanced, fate decreed that I should lose the stone, and my only consolation was, to discover afterwards, that had it been completed, its thickness and enormous refractive power would probably have caused the focus to fall within the substance of the stone.

"Having, however, in this experiment proved the possibility of working lenses of adamant, I set about another, and selected a rose-cut diamond, in order to form it into a plano-convex lens, and thereby save a moiety of the labour.

"In the progress of working this stone, the heat generated by friction, in the course of the abrasion of the diamond, was perpetually melting the cement (shell-lac) by which the flat side was affixed to the tool, and compelled me to seek some means by which it might be prevented. After several trials, I found, that when a portion of finely powdered pumice-stone was mixed with the shell-lac, the cement was much stronger, and less liable to melt, than any other similar substance.

"On the first of December 1824 I had the pleasure of first looking through a diamond microscope, and it was doubtless the first time this precious gem had been employed in making manifest the hidden secrets of nature. A few days after, I had polished it sufficiently to put it into the hands of Dr Goring, who tried its performance on various objects, both as a single microscope and as the objective of a compound. He states in a letter addressed to me, dated 3d

¹ Mr Pritchard informs us (see *Edinburgh Journal of Science*, No. 1, new series, p. 149, July 1829), that Messrs Rundell and Bridge of Ludgate Hill had, at the time when Mr Pritchard began his experiments, many Dutch diamond-cutters at work; and that the foreman, Mr Levi, with all his men, assured him, that it was impossible to work diamonds into spherical lenses. The same opinion, he adds, was also expressed by several others, who were considered of standard authority in such matters. When Mr Pritchard had, contrary to the expectation of many, succeeded in finishing his first lens, it was examined by Mr Levi, who expressed great astonishment at it, and added, that he was not acquainted with any means by which that figure could have been effected.

Single Mi-
croscopes.

January 1825, 'that it has shown the most difficult transparent objects I have submitted to it;' and again, 'I can clearly perceive the amazing superiority it will possess when completely finished.' I must, however, inform my readers, that we discovered in this state various flaws in the stone, in consequence of which we abandoned all thought of completing it. In this condition the project remained for about a year, when I determined to resume my attempts; and having worked several stones into lenses, I at last succeeded in obtaining a perfect one. In the course of these labours, a new though not unexpected defect appeared in several lenses, which would have subverted the whole scheme, had not the first diamond lens been free from it.

"These lenses, instead of giving a single image like the first, gave a double or triple one. This rendered them utterly useless as magnifiers, and made the defects of soft and hard parts in the same stone, and the small cavities in others, of comparatively trifling consequence. The images exhibited in such lenses overlapped each other, but were never entirely separated, though the quantity of overlapping varied in different specimens.

"It was now evident that these defects arose from polarisation, though this stone is described as 'refracting single.' I subsequently learned from Dr Brewster, after I had overcome these obstacles, that this property of the diamond had been observed by him, and an account of it given in the Edinburgh Philosophical Transactions.¹ On referring to his paper, it appears Dr Brewster found that some stones 'polarised in particular parts, while other portions of the same stone were quite free from any trace of polarity,' and thus perfectly adapted to our purpose, as had previously been demonstrated in the first diamond lens.

"Notwithstanding these difficulties, and the consequent expense and labour they entailed on me before sufficiently experienced in working upon this refractory material with certainty, I have now the satisfaction of being able, by inspection *a priori*, to decide whether a diamond is fit for a magnifier or not; and have now executed two plano-convex magnifiers of adamant, whose structure is quite perfect for microscopic purposes. One of these is about the twentieth of an inch focus, and is now in the possession of his Grace the Duke of Buckingham; the other, in my hands, is the thirtieth of an inch focus, and has consequently amplification enough for most practical purposes."²

As the expense of the diamond, and the labour of working it, are very great, about fifty or sixty hours being necessary to complete a diamond lens with double convexity, it is of the greatest consequence to ascertain beforehand if the substance of the diamond is homogeneous, that is, free from difference of density or double refraction, and if it does not contain any small cavities. The best way is to examine the stone, by cutting two flat faces upon it, unless it is a *laske* or table diamond, which always has two flat faces upon it; but this labour may often be avoided by examining it when plunged or held in a glass trough containing *oil of cassia*, the fluid which approaches nearest to it in refractive power. This will diminish all the refractions at the irregular surface of the diamond, and make any internal imperfections as easily seen as if its substance was plate-glass.

Aberration in lenses of diamond and glass compared. By comparing the indices of refraction of diamond and glass, it may be easily shown that the same magnifying power may be obtained with a *diamond* lens having its curvature with a radius of 8, as with a *glass* lens, the radius of whose curvature is 3; and as the spherical aberration increases with the depth of curvature or the thickness of

the lens, a lens of diamond will bear a much larger aperture than one of glass before indistinctness of vision is produced. Mr Pritchard has given a very useful ocular representation of the

relative value of a diamond and a glass lens. In the annexed figure, G is the section of a semi-lens of glass, and D the section of one of diamond, so placed that their principal focus F shall be at the same point. In the diamond semi-lens the marginal rays will intersect the axis at *d*, and in the glass semi-lens at *g*; the longitudinal aberration being *dF* in the *diamond*, and *gF* in the *glass* lens.

In order to obtain a numerical increase of these aberrations, Mr Pritchard computed them from the formula, and found that of the diamond lens to be $\frac{7}{8}$ ths of its own thickness, that of the glass lens being $\frac{7}{8}$ ths of its thickness; and by taking the thickness of the diamond lens to be 255, while that of the glass is 758, he obtained $\frac{7}{8}$ ths of 255 = 108, and $\frac{7}{8}$ ths of 758 = 884, and hence it follows that *the actual aberration of a DIAMOND lens is only about one ninth of the aberration of a GLASS lens* of the same power and aperture.

If we suppose the diamond lens to be ground on the same tool with the glass lens, so as to have the same curvature, the same thickness, and the same diameter, the longitudinal aberration of the diamond will be to that of the glass lens as 43 is to 117, or nearly one third of it; and if we suppose the focal length of both to be $\frac{1}{80}$ th of an inch, the magnifying power of the diamond lens will be 2133, while that of the glass one will be only 800. In order that a lens of glass may have the same magnifying power as that of the diamond above mentioned, its focal distance would require to be only the 200th part of an inch.

The durability of the diamond lens is also another valuable property, which allows it to be burnished into a disc of metal, and taken out and cleaned without any danger of being scratched. In treating of microscopic doublets and achromatic microscopes, we shall have occasion to recur again to the diamond lens.

Sapphire Lenses.

The ruby and the sapphire are the same substance, Sapphire differing only in colour. Mr Pritchard has, with his usual success, executed many lenses of sapphire, which, though inferior to those of diamond, are vastly superior to the best executed lenses of glass. When a double convex lens of sapphire and one of plate-glass are ground to the same focus, so as to have the same aperture and magnifying power, their relative curvatures are as 5 to 3, and their thicknesses as shown in the annexed figure, where A is the section of a semi-lens of sapphire, whose focus is at F, and B a section of a semi-lens of glass, having its focus at the same point. This figure points out in the clearest manner another advantage of using the precious stones in place of glass. In small

lenses of glass, the thickness of the glass is such that there is no room between its anterior surface and the object for the admission of instruments for dissection, and not

Fig. 1.

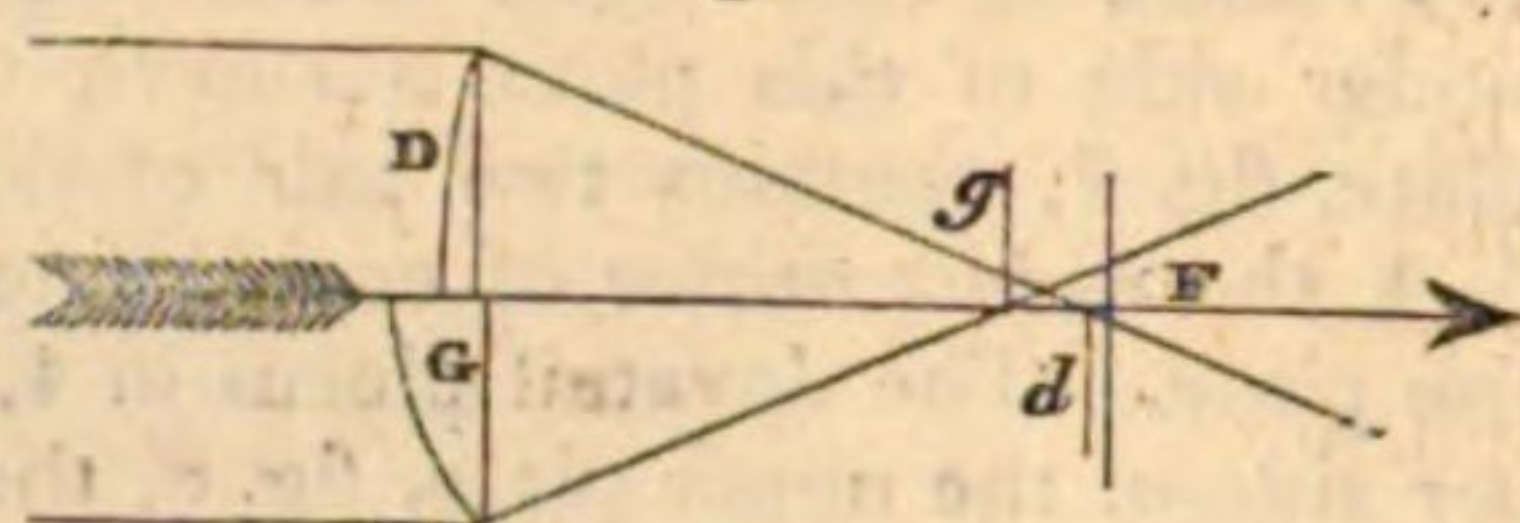
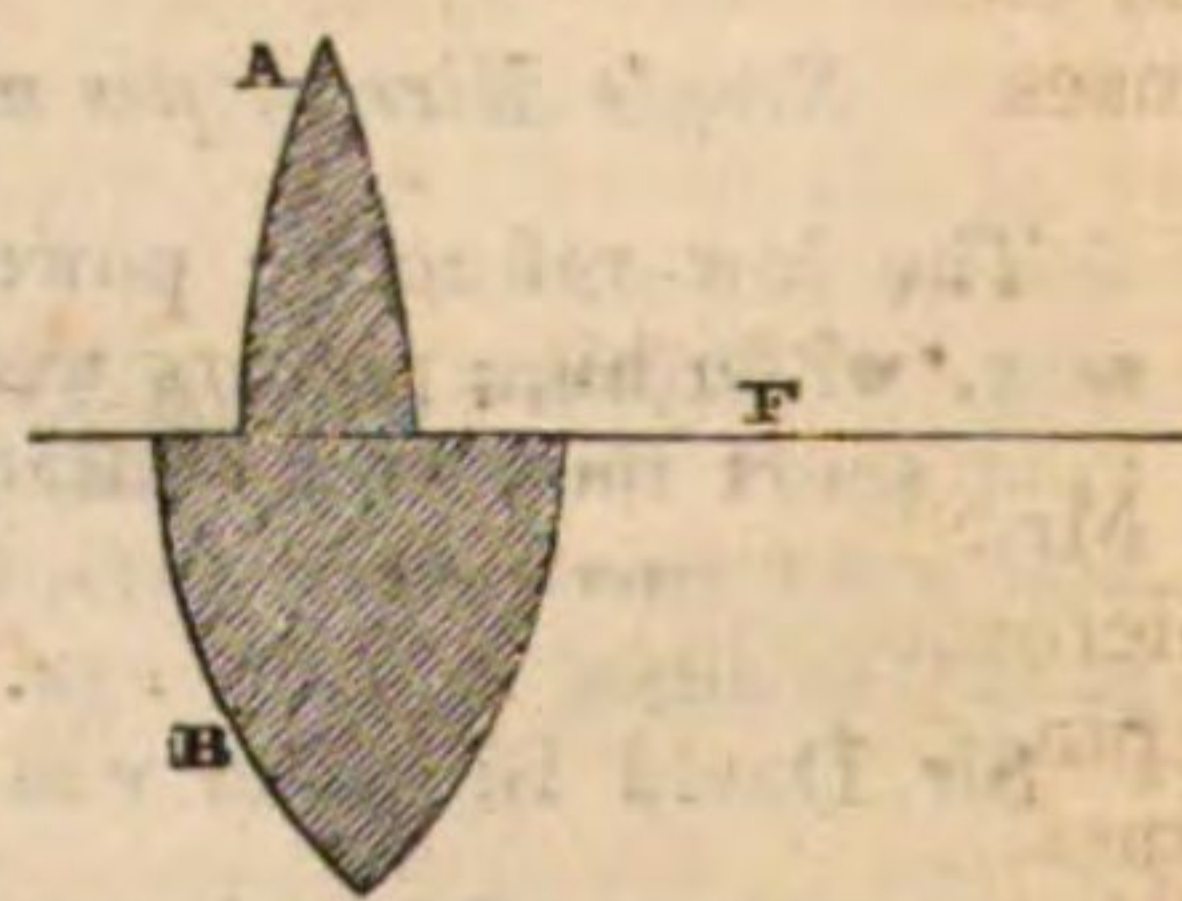


Fig. 2.



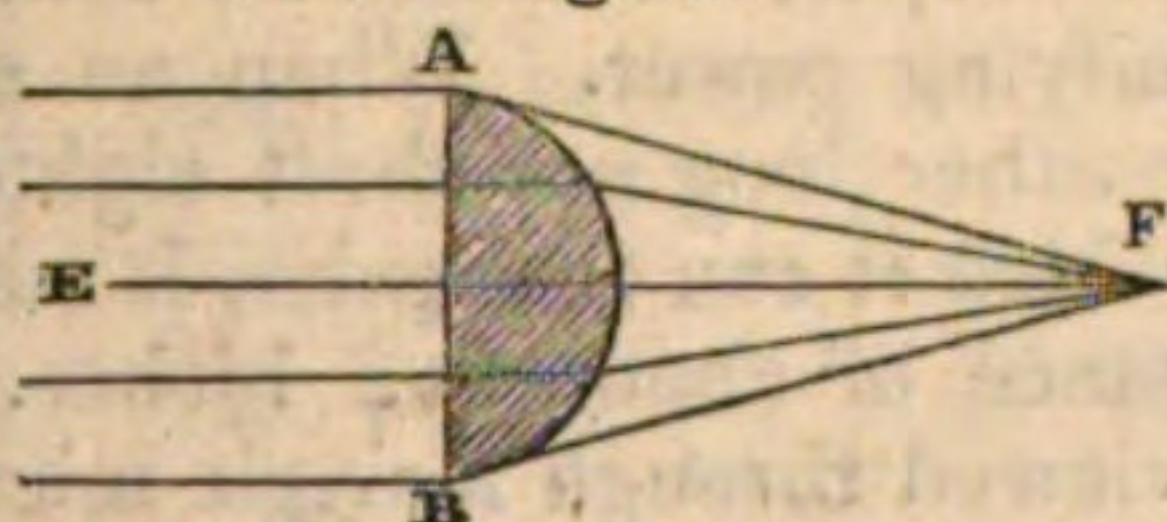
¹ Edinburgh Phil. Trans., vol. viii. p. 157, 1817. See also Geological Transactions, new series, vol. iii. p. 455; and London and Edinburgh Philosophical Magazine, vol. vii. p. 245.

² Microscopic Cabinet, p. 107-111.

Single Microscopes. — even for the thinnest plate of glass, so that it is impossible to use glass lenses of small foci in viewing objects placed in glass sliders. If the preceding figure represents lenses with a focus of $\frac{1}{30}$ th of an inch, the distance of the glass lens B from F will be little more than $\frac{1}{60}$ th of an inch, which is less than the thinnest glass.

In using the *sapphire* and *ruby*, or any precious stone which refracts doubly, such as *zircon*, *topaz*, &c. for lenses, we are exposed to a very serious defect, arising from the duplication of minute lines, in consequence of the double refraction of these crystals. In order to remedy this defect, the optician endeavours to cut the stone so that the axis of the lens may coincide with the axis of double refraction. This, however, is a difficult task; and, even if it were accomplished, we should not get rid entirely of the duplication of the images, as in all double convex lenses, as well as in plane convex lenses with the plane side turned to the object, the rays cannot pass through the lens in parallel directions, and therefore must suffer double refraction, however small. It may be reduced, however, to the smallest possible amount, and even to nothing, for pencils of rays diverging from a point in the axis, by making the lens plano-convex, and turning the plane side to the eye, as in the annexed figure, where rays issuing from F, and entering the eye parallel at E, must pass through the lens AB in parallel directions, suffering all their refraction at the first or curved surface of the lens. By adopting this form and position of the lens, we, however, lose more than we gain; for the lens is placed in the position which gives a maximum spherical aberration. When the magnifying power is not very high, the residual double refraction is not injurious; and in proof of this we may state, that we have in our possession a double convex lens of sapphire, executed by Mr Pritchard, which exhibits minute objects with the greatest beauty and precision. The only way, therefore, is to employ precious stones, such as the *diamond*, the *garnet*, and the *spinelle ruby*, which have no double refraction when their crystallization has been regularly effected.

Fig. 3.



Garnet and Spinnelle Ruby Lenses.

Garnet and spinelle lenses. The garnet is superior in its structure to the spinelle ruby, and the best and purest which we have seen is that which is brought from Greenland, and has a slight tinge of purple. We have used lenses made of this substance by Mr Hill, Mr Adie, Mr Blackie, and Mr Veitch, all of which exhibit minute objects with admirable accuracy and precision; and we can state with confidence, that we have never experienced the slightest inconvenience from the colour of the garnet, which diminishes with its thickness, and consequently disappears almost wholly in very minute lenses.

Single Fluid Microscopes.

Single fluid microscopes.

Mr Stephen Gray long ago proposed to construct single microscopes with drops of water, which he lifted up with a pin, and deposited in a small hole made in a piece of brass. The drop retained a sort of imperfect sphericity, and showed objects with some distinctness; but it is obvious that the very weight of the drop destroyed its spherical form, even if it had not been disturbed by minute irregularities on the circumference of the aperture in which it was placed.

Sir David Brewster long ago constructed fluid lenses in a different manner, so as to avoid the irregularities above

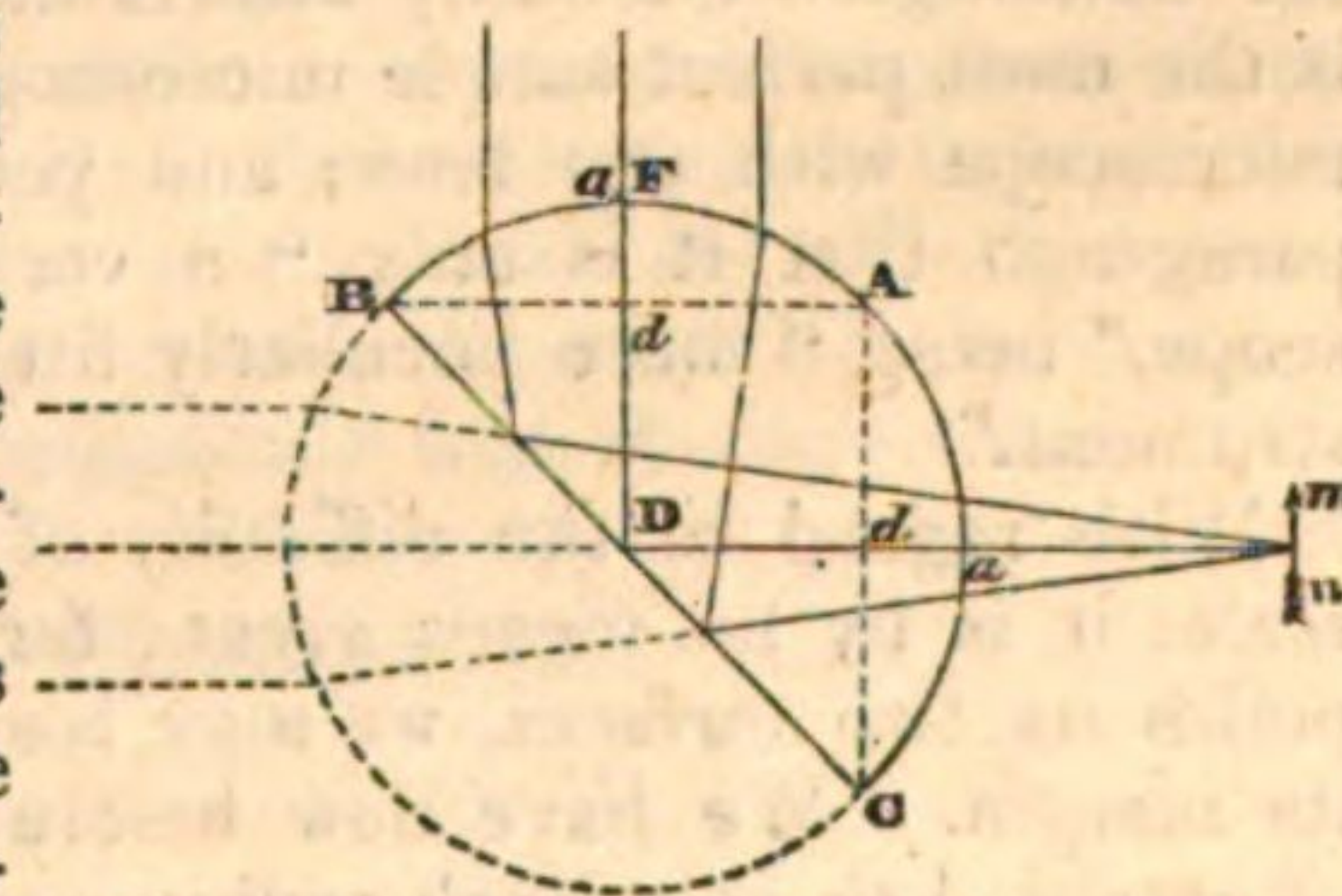
mentioned. He placed minute drops of very pure turpentine varnish, and other viscid fluids, on plates of thin and parallel glass. By this means he formed plano-convex lenses of any focal length; and by dropping the varnish on both sides, he formed double convex lenses, with their convexities in any required proportion. By freeing the glass carefully from all grease with a solution of soda, the margin of these lenses was beautifully circular; and the only effect of gravity, which diminishes with the viscosity of the fluid and with the smallness of the drop, is to elongate the lower lens and flatten the upper one. These lenses were found to answer well as the object-glasses of compound microscopes.

After experiencing the extreme difficulty of obtaining precious stones free of double refraction or difference of density, and from little cavities and imperfections, as well as the difficulty of giving their surfaces a perfect polish and a correct figure, Sir David Brewster has, we understand, recently made an extended series of experiments on the formation of minute fluid lenses, which should equal in power and distinctness those made of precious stones. The primary difficulty which was encountered in this attempt was that of depositing a sufficiently minute drop of fluid upon a surface of glass. This arose from two causes, from the difficulty of taking up on the slenderest fibre a minute globule of a fluid of any moderate tenacity, and the still greater difficulty of overcoming its adhesion to the fibre, and laying a portion of it on glass. The first of these difficulties he overcame by a suitable mixture of two fluids, and the second by a mechanical process. Having thus succeeded in obtaining lenses too small to be recognised distinctly by the eye, he next endeavoured to make their figure approximate to the hyperbolic form when the lenses were not of the smallest size, and the results which he obtained were far beyond his expectation. Some of these lenses preserved their perfection for more than a year, and if protected from dust might have been kept much longer. If fluids could be obtained of a high refractive power, and not of a volatile nature, microscopes of extreme perfection might thus be readily constructed.

Catadioptric Lenses.

A single lens, by which light is both refracted and reflected, seems at first sight to be something paradoxical. Such a lens, however, which was proposed and used by Sir David Brewster, is shown in the annexed figure, where

Fig. 4.



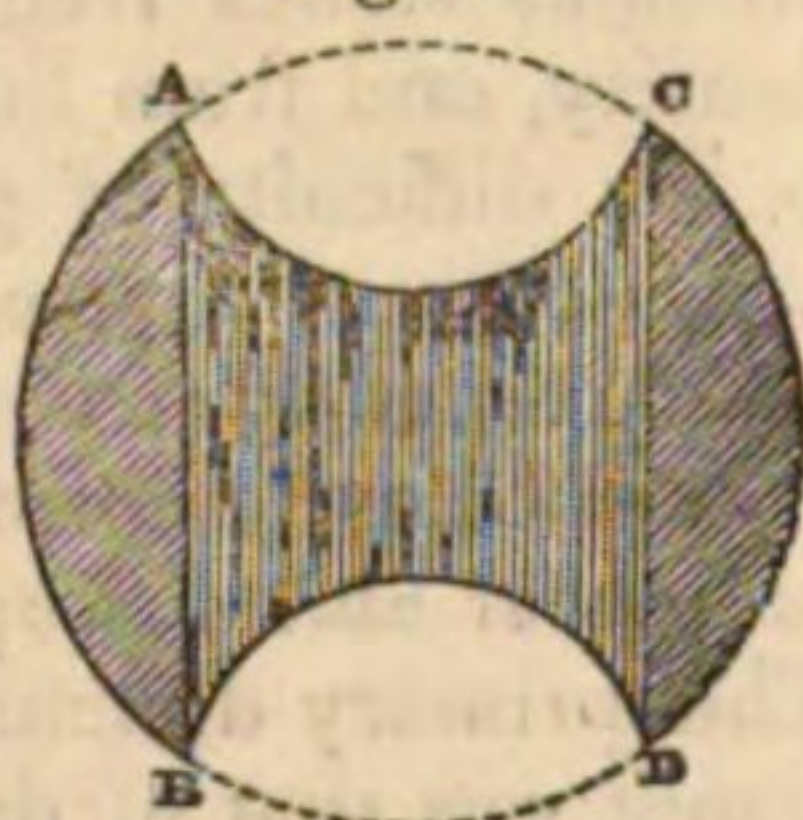
sect the semicircle BAC in A, and join AB, AC. If we now place an object at *mn*, and look into the lens BA at F, we shall see by reflection from the surface BC the object *mn*, with the same distinctness and under the same angle as if we had placed the two lenses Aa Bd, Aa Cd, with their plane sides AB, AC together. Since the light is incident on the reflecting surface BDC at an angle of 45°, not a ray of it will be lost, as it suffers total reflection. The lens thus used has less spherical aberration than when used as a whole, ABC, and there is no error from imperfect centring. This lens may be used as the object-glass of a compound microscope; and it will be seen in another

Single Microscopes. section that it possesses other advantages than those which have been mentioned.

The Grooved Sphere.

The grooved sphere. This lens derives its name from its having a deep groove cut round it in the plane of a great circle perpendicular to the axis of vision. Sir David Brewster was led to its construction by the doublet of Dr Wollaston, which will be described in another section. It consists of a spherical lens or sphere, with a deep concave groove cut round it, so as to cut off the marginal pencils, and thus give a wider field and a more perfect image. It is represented in the annexed figure, where ABCD is a sphere of glass, having the unshaded parts below AC and above BD cut away, in order to prevent rays that fall very obliquely from reaching the eye. The central thickness of the lens may be made so small as to render the spherical and even the chromatic aberration almost insensible. As all the pencils pass through the centre, every part of the image will be equally distinct; a property possessed by no other lens whatever.

Fig. 5.



Mr Coddington,¹ who entertains a high opinion of the value of this lens, observes: "Besides all this, another advantage appears in practice to attend this construction, which I did not anticipate, and for which I cannot now at all account. I have stated, that when a pencil of rays is admitted into the eye, which, having passed without deviation through a lens, is bent by the eye, the vision is never free from the coloured fringes produced by eccentric dispersion. Now with the sphere I certainly do not perceive this defect, and I therefore conceive that if it were possible to make the spherical glass on a very minute scale, it would be the most perfect simple microscope, except, perhaps, Dr Wollaston's doublet,² than which I can hardly imagine any thing more excellent, as far as its use extends, its only defects being the very small field of view, and the impracticability of applying it, except to transparent objects seen by transmitted light. Now the sphere has this advantage, that whereas it makes a very good simple microscope, it is more peculiarly fitted for the object-glass of a compound instrument, since it gives a perfectly distinct image of any required extent, and that, when combined with a proper eye-piece, it may without difficulty be employed for opaque objects." We do not rightly apprehend the exact import of these observations, Mr Coddington distinctly asserts that the grooved sphere is the most perfect simple microscope, or the most perfect microscope with one lens; and yet he says in the next paragraph that it is only "a very good simple microscope," being "more peculiarly fitted for a compound instrument."

With regard to the difficulty of making it on a small scale, it is by no means great; for if we can grind and polish its two surfaces, we may readily excavate it round its margin. We have now before us a grooved sphere of garnet $\frac{1}{2}$ th of an inch radius, executed by Mr Blackie: The focus is almost close to the lens, which in many kinds of observation is a great advantage, and its performance is remarkably fine.

It will be seen in our article on OPTICS, that when the refractive index of a sphere exceeds 2.000, its focus falls within the sphere. Hence a grooved sphere made of diamond is useless. When made with garnet, it is invaluable,

and its focus is just thrown so near its surface, that the objects may be laid upon its surface, or pressed against it by a concave surface of the same radius.

Crystalline Lenses of Small Fishes.

The crystalline lens of minnows and small fishes may be taken out of the eye in a state of such perfection, that, when used as single microscopes, they give a very perfect image of minute objects. In such lenses which have an increasing density towards their centre, the spherical aberration is almost wholly corrected. Great care, however, must be taken to make the axis of the lens the axis of vision, to prevent its form from being injured by pressure against the aperture which holds it. The best way is to make a ring at the end of a piece of wire, having its diameter a little greater than that of the lens. A ring of viscid fluid is then made to line the ring of wire, and the lens is suspended in the ring of fluid, some of the fluid encroaching upon its anterior or posterior surface.

Magnifying Power of Single Microscopes.

Having thus described the various kinds of single microscopes, we shall now consider the subject of their magnifying power. When an eye in the prime of life, and neither long nor short sighted, views the minutest object which it can recognise, it will generally place it at the distance of about five inches. When the same object is viewed through a single microscope, the distance at which it is seen is equal to the focal length of the lens; and as the apparent magnitude of objects is inversely as the distances at which they are seen, we have only to divide the distance five inches by the focal length of the lens, in order to know its magnifying power, or its apparent magnitude when seen through the lens.

The following table shows the magnifying power of lenses of all focal lengths, from 5 inches up to the 100th of an inch, and is applicable to all lenses, of whatever substance they are made.

Focal Length.	Magnifying Power.	Focal Length.	Magnifying Power.
Inches.		Inches.	
5	1	$\frac{1}{16}$	80
2	$2\frac{1}{2}$	$\frac{1}{17}$	85
$1\frac{3}{4}$	$2\frac{2}{3}$	$\frac{1}{18}$	90
$1\frac{1}{2}$	$3\frac{1}{3}$	$\frac{1}{19}$	95
$1\frac{1}{4}$	4	$\frac{1}{20}$	100
1	5	$\frac{1}{25}$	125
$\frac{3}{4}$	$6\frac{2}{3}$	$\frac{1}{30}$	150
$\frac{2}{3}$	10	$\frac{1}{33}$	175
$\frac{1}{2}$	15	$\frac{1}{40}$	200
$\frac{1}{3}$	20	$\frac{1}{45}$	225
$\frac{1}{4}$	25	$\frac{1}{50}$	250
$\frac{1}{5}$	30	$\frac{1}{55}$	275
$\frac{1}{6}$	35	$\frac{1}{60}$	300
$\frac{1}{7}$	40	$\frac{1}{65}$	325
$\frac{1}{8}$	45	$\frac{1}{70}$	350
$\frac{1}{9}$	50	$\frac{1}{75}$	375
$\frac{1}{10}$	55	$\frac{1}{80}$	400
$\frac{1}{11}$	60	$\frac{1}{83}$	425
$\frac{1}{12}$	65	$\frac{1}{90}$	450
$\frac{1}{13}$	70	$\frac{1}{93}$	475
$\frac{1}{14}$	75	$\frac{1}{100}$	500

¹ Phil. Trans. 1830, part i. p. 69-84.

² This exception was needless, as the doublet is not a simple microscope, having two lenses placed at a distance.

Single Mi-
croscopes.
On the
spherical
aberration
of lenses.

We have already mentioned the advantages which the precious stones have over glass ones, in having a much less spherical aberration. In order that a glass lens may have the least spherical aberration, its radii of curvature must be as one to six, the flattest side being turned to the object; but this is not the case with bodies of a different refractive power. Mr Coddington, in his valuable Treatise on the Reflection and Refraction of Light,¹ has computed the ratio of the curves when the aberration is a minimum for various indices of refraction from 1.5 up to 2.0, and the amount of the aberration itself in parts of the thickness of the lens. This table is very important in a practical point of view, as will be seen from the observations which follow it.

Table showing the Spherical Aberration of Lenses of Glass and the Precious Stones, and the proper proportion of their Radii when the Aberration is a Minimum.

Substances.	Index of Refrac- tion.	Ratio of the Radii of a Lens of Mini- mum Aber- ration.	Longitu- dinal Aber- ration, the thickness being 10.
Fluor spar.....	1.4	1 to 3.66	10.96
Cryolite.....			
Glass plate.....			
Oil of almonds.....	1.5	1 to 6	10.71
Castor oil.....			
Honey.....			
Flint glass.....	1.6	1 to 14	9.33
Quartz.....			
Topaz.....			
Oil of cassia.....	1.7	1 to — 93	6.66
Glass, lead 1, flint 2....			
Sulphuret of carbon....			
Sapphire.....	1.8	1 to — 12	3.57
Ruby.....			
Spinel ruby.....			
Garnet.....	1.9	1 to — 7	1.66
Glass, lead 2, flint 1½..			
Sulphate of lead.....			
Glass, lead 2½, flint 1..	2.0	1 to — 5	0.62
Zircon.....			
Calomel.....			
Sulphur.....			
Phosphorus.....			
Glass, lead 3, flint 1....			

It appears from the preceding table, that when the refractive index is between 1.4 and 1.6 and a little more, but less than 1.7, the second surface of the double convex lens must be *convex*, in order to have the least spherical aberration; but that when the index is above 1.6 or a little more, the second surface must be *concave*, in order to make the aberration a minimum, and this concavity, in the case of zircon and sulphur, is so much as — 5, so that in diamond it must be nearly — 3; so that we must sacrifice a great deal of magnifying power in order to obtain this advantage in diamond; but the sacrifice will be well bestowed, for such a lens will be almost wholly free of spherical aberration. It appears from the table, that when the index of refraction is a little less than 1.7, a plano-convex lens, with its plane side turned to the object, is the best form for a single microscope.

Notwithstanding the difficulty of the task, we would earnestly direct the attention of artists to the subject of grinding plano-convex lenses of a hyperbolic form for

single microscopes. The smallness of a lens must increase the difficulty; but in this case the effect may be accidentally obtained, as it is often done in giving a parabolic and an elliptical form to specula. Mr Potter has given, and put to the test of experiment, a method of obtaining any curve derived from revolution, by giving a particular form to the grinding and polishing tools.²

Microscop-
ic Doub-
lets and
Triplets.

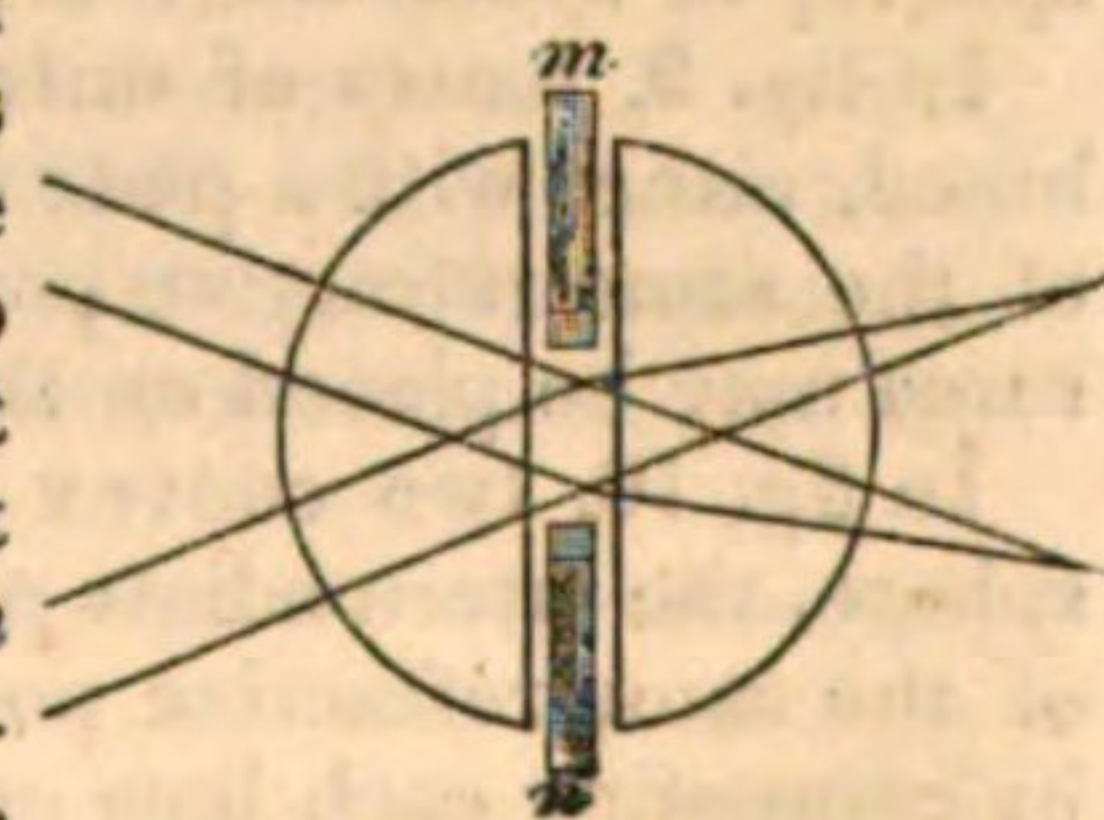
CHAP. II.—DESCRIPTION OF MICROSCOPIC DOUBLET AND TRIPLETS.

Under this chapter we propose to describe all combinations of lenses in which two or more are placed in contact, or at such a distance that no image is formed between them.

Wollaston's Periscopic Doublet.

The earliest proposal of a doublet lens was that which Wollaston described in 1812,³ under the name of a periscopic microscope. The following is his own description of it: "The great desideratum," says he, "in employing high magnifiers, is sufficiency of light; and it is accordingly expedient to make the aperture of the little lens as large as is consistent with distinct vision. But if the object to be viewed is of such magnitude as to appear under an angle of several degrees on each side of the centre, the requisite distinctness cannot be given to the whole surface by a common lens, in consequence of the confusion occasioned by oblique incidence of the lateral rays, excepting by means of a very small aperture, and proportionable diminution of light. In order to remedy this inconvenience, I conceived that the perforated metal which limits the aperture of the lens might be placed with advantage in its centre; and accordingly I procured two plano-convex lenses ground to the same radius, and applying their plane surface on opposite sides of the same aperture, in a thin piece of metal (as is represented by a section, fig. 6), I produced the desired effect, having virtually a double convex lens, so contrived that the passage of oblique pencils was at right angles with its surface, as well as the central pencil. With a lens so constructed, the perforation that appeared to give the most perfect distinctness was about *one-fifth* part of the focal length in diameter; and when such an aperture is well centred, the visible field is at least as much as 20° in diameter. It is true, that a portion of light is lost by doubling the number of surfaces; but this is more than compensated by the greater aperture which, under these circumstances, is compatible with distinct vision."

Fig. 6.



Periscopic Sphere.

In the preceding passage Dr Wollaston describes only Periscopic a double convex periscopic microscope, consisting of two plano-convex lenses; but he does not take the case where these two lenses are hemispheres, and, consequently, where the doubly convex one which they form is a sphere. When the lenses are not hemispheres, the pencils are not central, and the rays from different parts of the object do not each suffer the same species of refraction as they do when passing through a sphere, so that every part of the field is not equally distinct. It is obvious also that Dr Wollaston did not think of filling up the central aper-

¹ Page 111, Cambridge, 1829.

² Edinburgh Journal of Science, new series, No. 12.

³ Phil. Trans. 1812, p. 375.

Microscopic
Doublets
and
Triplets.

ture with a fluid of the same refractive power as the lens, in order to remove the loss of light from the double number of surfaces, which he mentions as a defect in his microscope.

The construction of a periscopic sphere proposed by Sir David Brewster combines these two properties. The lenses, whether they are hemispherical or not, must be so placed that their convex surfaces form part of the same sphere, as shown in the annexed figures.

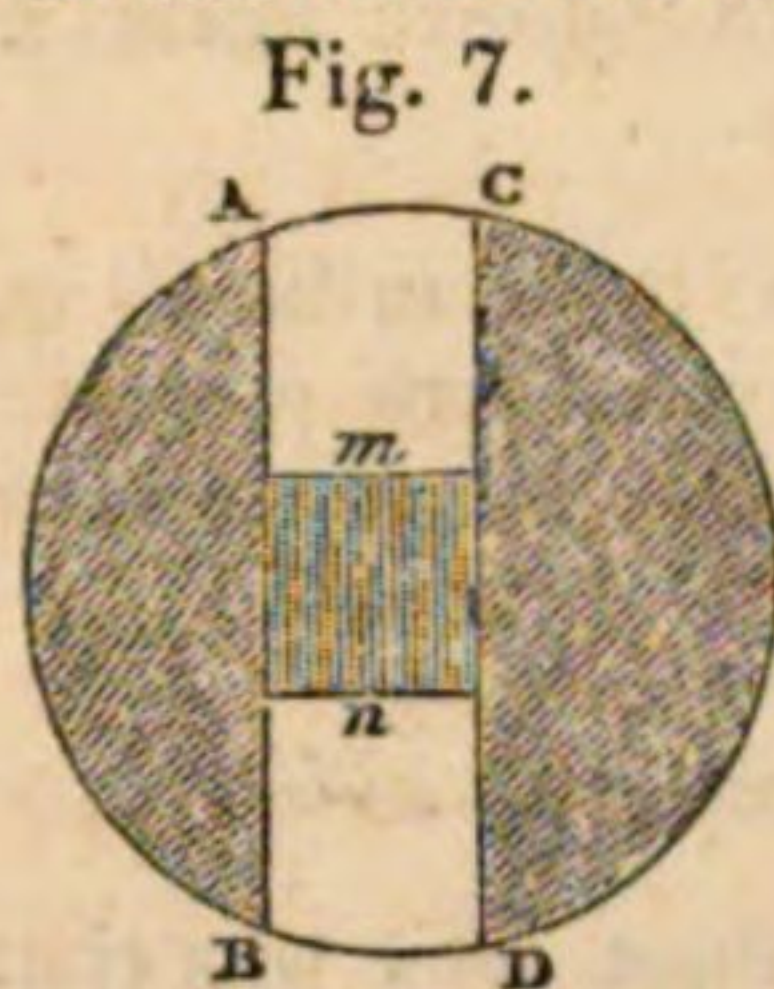


Fig. 7.

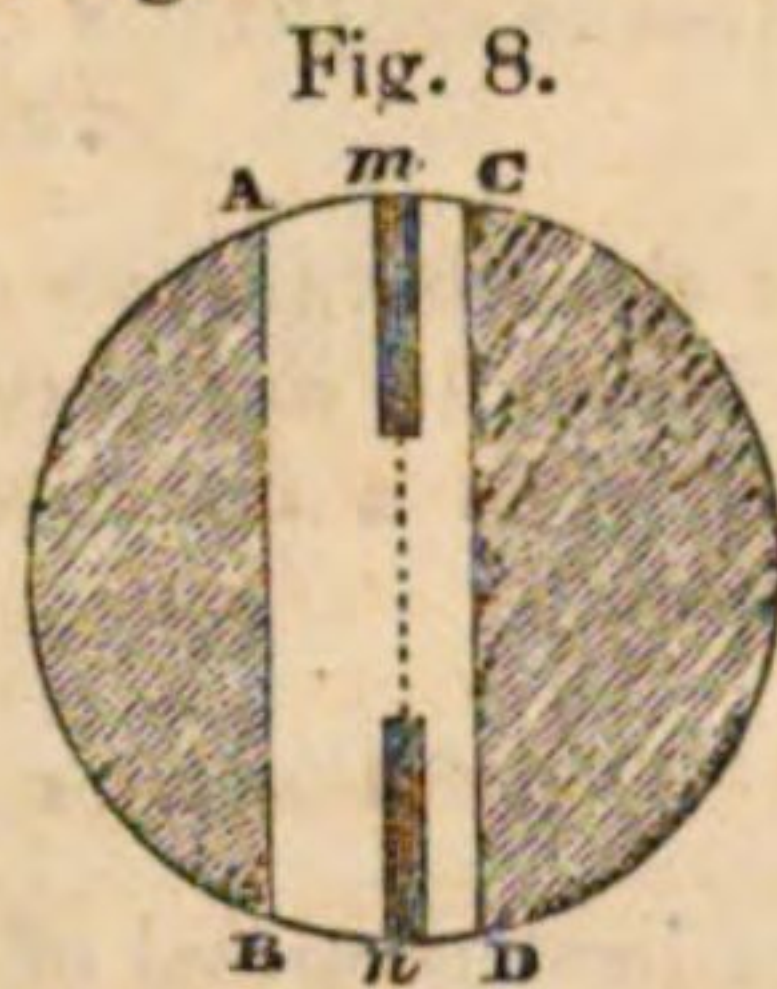


Fig. 8.

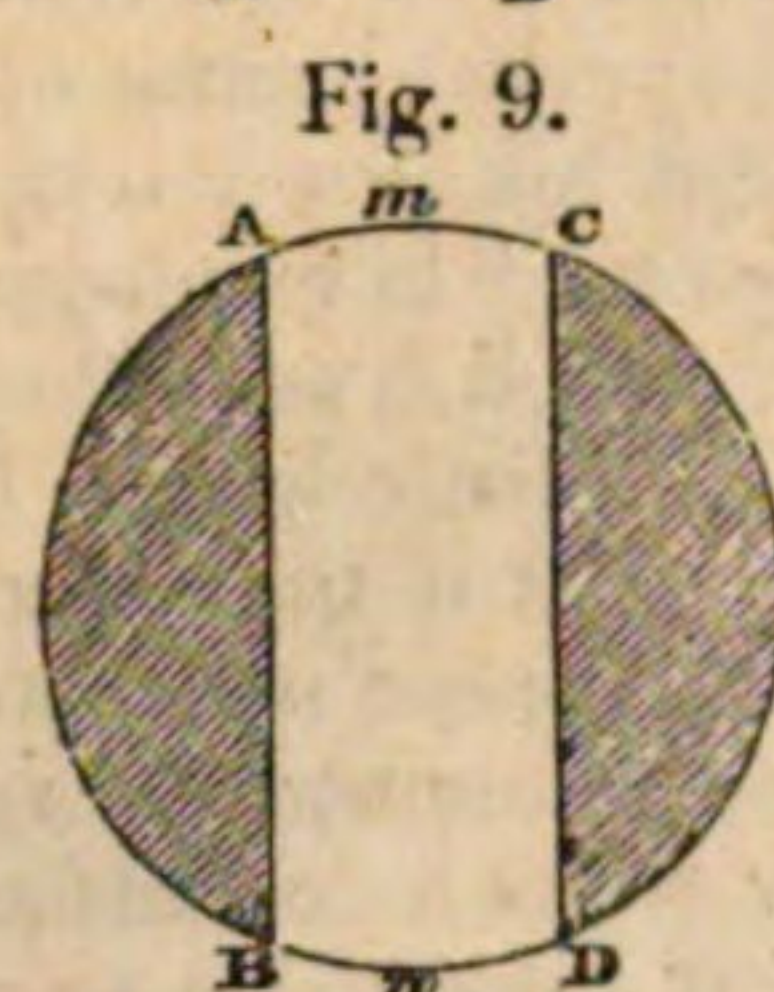


Fig. 9.

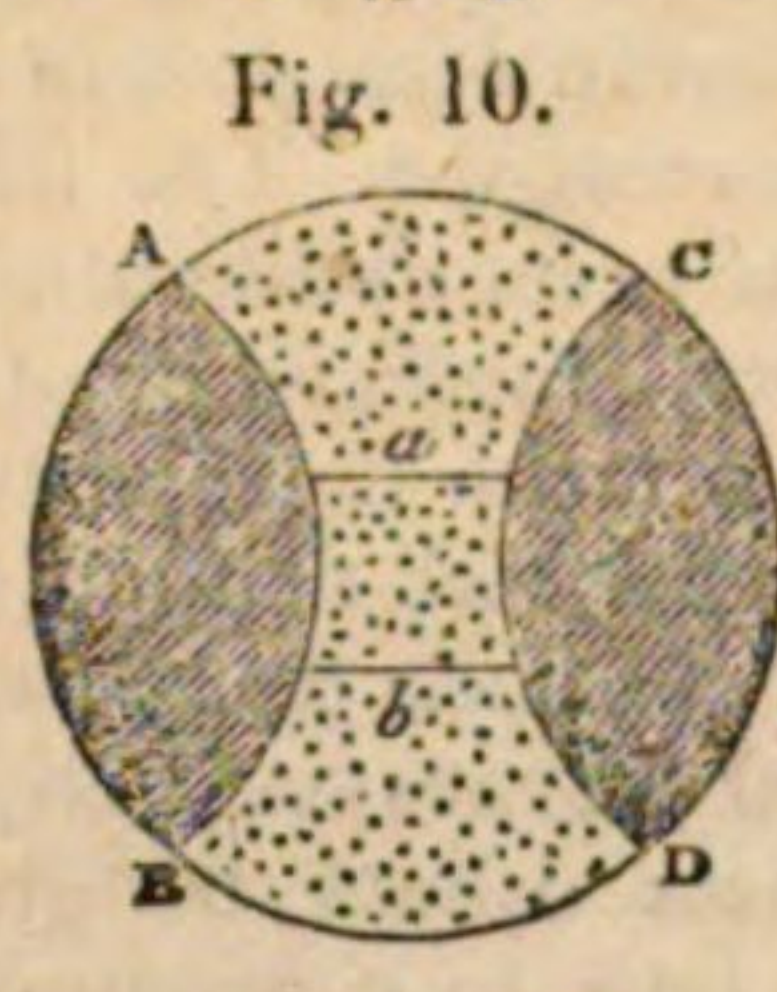


Fig. 10.

In fig. 7, the plano-convex lenses AB, CD may be cemented to a piece of plate-glass *mn*, of such a thickness in one direction as to complete the sphere, and of such a diameter in the direction *mn* as to form a suitable contraction of the aperture.

In fig. 8, the space between the lenses may be filled up, as in the figure, by two pieces of plate-glass *AmnB*, *CmnD*, between which is a plate of brass, or of thin black paper, containing a suitable aperture in the centre of the lenses. Here there are *six* surfaces within the sphere, but, by uniting them with a proper cement, the whole becomes a single sphere, in which there is no perceptible loss of light.

In fig. 9, lenses of unequal size and thickness are combined, either with a plate of glass, or a fluid between them of the same refractive power as the glass, and the apertures may be placed on the plane surfaces AB, CD.

In fig. 10, two convex lenses may be combined into a sphere, the intermediate portion being filled up with a fluid of the same refractive power. This may be readily done by cementing each lens on the end of a brass or glass tube *ab*, and introducing the fluid by an aperture.

In uniting these lenses, it is obviously necessary that the convex outer surfaces should be exactly of the same curvature, and of the same kind of glass. The best way of effecting this is to grind a thick lens ABC, either greater or less than a hemisphere, and then to bisect it at AD, and out of the portions ADB, ADC to form two plano-convex or two double convex lenses AB, CD. The outer surfaces of these two lenses will belong accurately to the same sphere. The perfect similarity of the inner surfaces is of less consequence, as all refraction by them is removed by the cement.

By these different steps Sir David Brewster was led to the idea of the grooved sphere, or the lens already de-

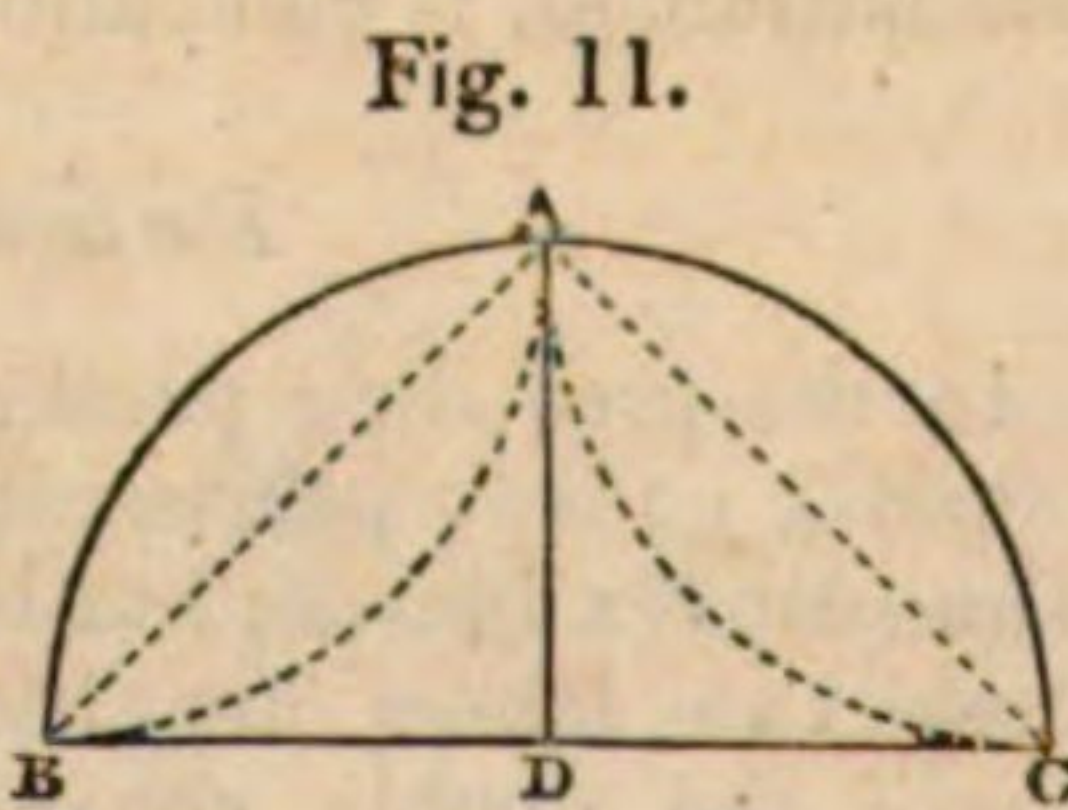


Fig. 11.

scribed under the head of single microscopes, in which the aperture is contracted by excavating the sphere all round in one of its great circles.

Periscopic Achromatic Spheres.

If, in the construction shown in fig. 12, in place of making the fluid *op* of the same refractive and dispersive power as the two lenses, we make it such as to correct the colour of these lenses, we shall obtain an achromatic sphere, as proposed by Sir David Brewster; and the compound lens may be still farther improved as a microscope, by attaching, either by cement or not to the back of the first lens AB, a convex speculum of silver or steel for illuminating the object, the contracted aperture being the hole in the centre of the speculum. The concave fluid lens is shown at *op*; and such a curvature must be given to the convex reflector *mn*, that it may reflect parallel or diverging rays upon the object.¹

Mr Coddington,² in his excellent treatise on optics, thus treats of the preceding contrivance.

"An achromatic sphere may be constructed by interposing between two crossed lenses (double convex ones), in opposite positions, a concave lens of a medium more highly dispersive than that of the lenses, adjusting the curvatures so that the outer surfaces of the crossed lenses shall be portions of the same sphere, and that the interior surfaces shall exactly fit into each other.

"In such a system, we may consider the effect to be the same as that of an entire sphere of the same medium as the two lenses diminished by that of a concave lens having for its refractive ratio that which exists between the two media in question.

"Thus, if μ_1 be the ordinary index of refraction for the convex lenses, μ_2 for the concave one, $\pi:1$ the ratio of the dispersive powers, r the radius of the sphere, s, σ those of the internal surfaces, we must have

$$\left(\frac{\mu_2}{\mu_1} - 1\right) \left(\frac{1}{s} + \frac{1}{\sigma}\right) : 2 \frac{\mu_1 - 1}{\mu_1} \frac{1}{r} = \pi : 1;$$

whence it follows, that $\frac{1}{s} + \frac{1}{\sigma} = 2\pi \frac{\mu_1 - 1}{\mu_2 - \mu_1} \frac{1}{r}$.

For example, let $\mu_1 = 1.5$; $\mu_2 = 1.65$; $\pi = 1.25$.

Then, $\frac{1}{s} + \frac{1}{\sigma} = \frac{1}{4} \cdot \frac{.5}{1.5} \frac{1}{r} = \frac{1}{12r}$.

If the first internal surface be plane, or $s = \infty$, we have

in general $\sigma = \frac{1}{2\pi} \frac{\mu_2 - \mu_1}{\mu_1 - 1} r$; or, in this particular example, $\sigma = 1.2r$, or $\sigma:r = 6:5$.

Doublet of no Aberration.

So long ago as 1668, a doublet was described in the Philosophical Transactions, in which a large and flat field was obtained. This subject, however, was never investigated with care till Sir John Herschel took up the subject in 1821. The doublet, made of glass, which Sir John proposes for obtaining perfect distinctness in microscopi-

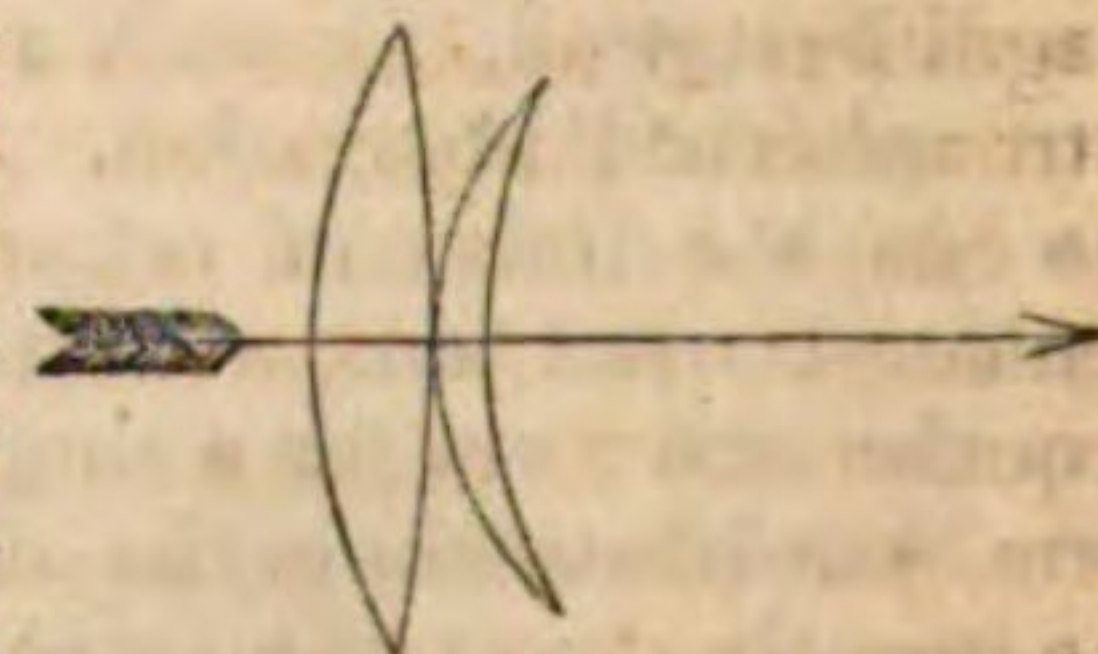


Fig. 13.

¹ Edinburgh Philosophical Journal, vol. iii.; and Mr Pritchard's Treatise on Optical Instruments, in the Library of Useful Knowledge, p. 41, § 66.

² Treatise on the Reflection and Refraction of Light, p. 256.

Microscopic observations is shown in the annexed figures, 13, 14, the convex sides being turned to the eye when the doublet is used as a microscope, and to the sun when it is used as a burning-glass. The following are the radii and focal length of these lenses.

Fig. 14.

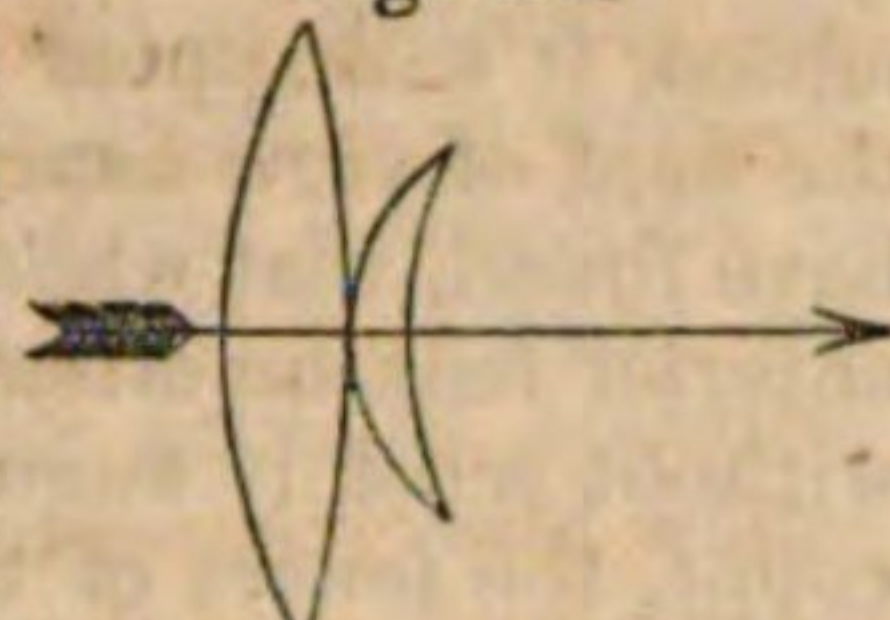


Fig. 13.

Fig. 14.

Focal length of the first lens.....	+ 10.000	+ 10.000
Radius of its first surface.....	+ 5.833	+ 5.833
Radius of its second surface.....	— 35.000	— 35.000
Focal length of the second lens.....	+ 17.829	+ 5.497
Radius of its first surface.....	+ 3.688	+ 2.954
Radius of its second surface.....	+ 6.291	+ 8.128
Focal length of the combined lenses	+ 6.407	+ 3.474

"Whether we ought or ought not," says Sir John, "to aim at the rigorous destruction of rays parallel to the axis, the use to which the lens is to be applied must decide. In a burning-glass it is of the highest importance. A slight consideration will suffice to show, that the difference of temperatures produced in the foci of a double convex lens of equal radii, and one of the same focal length, but of the best form, must be very considerable. In order to try whether even the latter might not be improved by the shortening of the focus, and the superior concentration of the exterior rays, by applying a correcting lens of one of the forms above calculated, in spite of the loss of heat in passing through a second glass, I procured two lenses to be figured to the radii assigned in the first column of the foregoing table. They were about three inches in aperture, and when combined as above described, the aberration was almost totally destroyed, and probably would have been so completely had the index of refraction proper to the glass been employed instead of that adopted in our calculation for brevity. Their combined effect as a burning-lens appeared to me decidedly superior to that of the first lens used alone, and there is therefore good reason to presume, that the effect of the other construction, which, with the same loss of heat, affords a much greater contraction of the focus, would be still better; and I regret not having tried it in preference.

"In eye-glasses and magnifiers, if we would examine a minute object with much attention, as a small insect, or (when applied to astronomical purposes) if we would scrutinize the appearance of a planet, a lunar mountain, the nucleus of a comet, or a close double star, where extent of field is of less consequence than perfect distinctness in the central point, too much pains cannot be taken in destroying the central aberration."¹

Mr Pritchard informs us, that he has executed some of these doublets for the object-glasses of compound microscopes, "for which," he says, "they answer remarkably well, but their angle of aperture is small compared with combinations of double achromatics."²

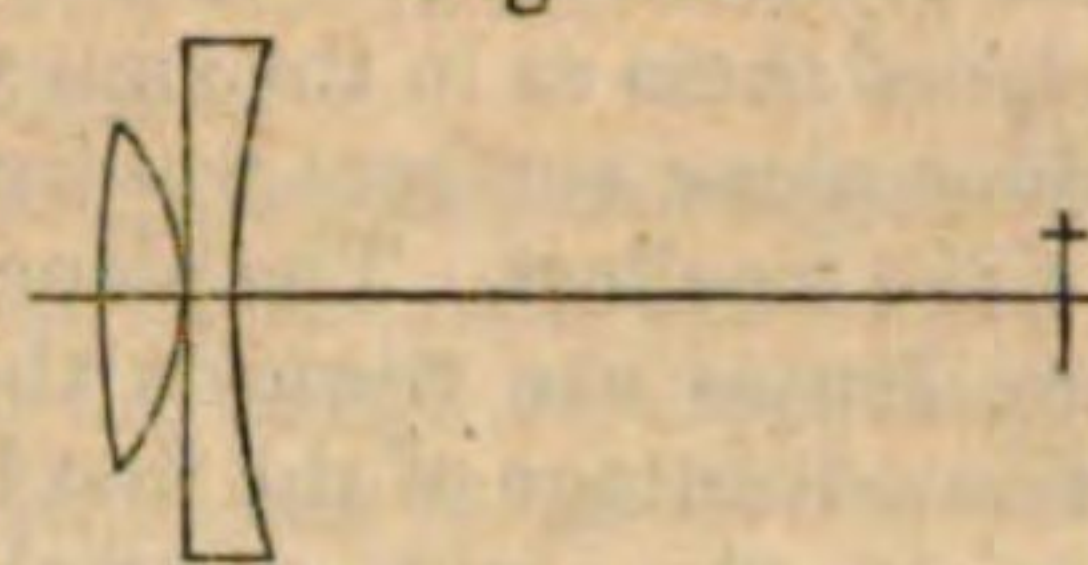
Herschel's Periscopic Doublet.

Herschel's periscopic doublet.

We owe also to Sir John Herschel the construction of a periscopic doublet with a very large field of moderate distinctness. "In spectacles," says he, "reading-glasses, magnifiers of moderate power, and eye-glasses for certain astronomical purposes, the correction of the aberration in the centre of the field may be sacrificed with little inconvenience. By far the best periscopic combination I am acquainted with consists of a double convex lens of the best form, but placed in its worst position (radii as 6 to 1) for the lens next the eye, and a plane concave whose focal

length is to that of the other as 2.6 to 1, or as 13 to 5, placed in contact with its flatter surface, and having its concavity towards the object, as in the annexed figure, for the farthest; yet for destroying the aberration of rays parallel to the axis nothing can be worse. In fact our formula gives for the aberration in this construction 22.02, or about 22 times what the best single lens of equal power would give; yet, on accidentally combining two such lenses in this manner, I was immediately struck with the remarkable extent of oblique vision, with the absence of fatigue on reading some lines with a power much beyond that of the natural eye, and with the freedom from colour at the edges of the field, arising from the opposition of the prismatic refractions of the two solids, an advantage which a single meniscus does not possess." The focal length of the compound lens which Sir John tried was 1.84 of an inch. The field of tolerably distinct vision extended fully 40° from the axis, and the letters of a book might be read, and the forms of objects distinguished, with management, as far as the 75th degree. In using such a combination the lenses should be very thin, and the eye applied as close as possible.

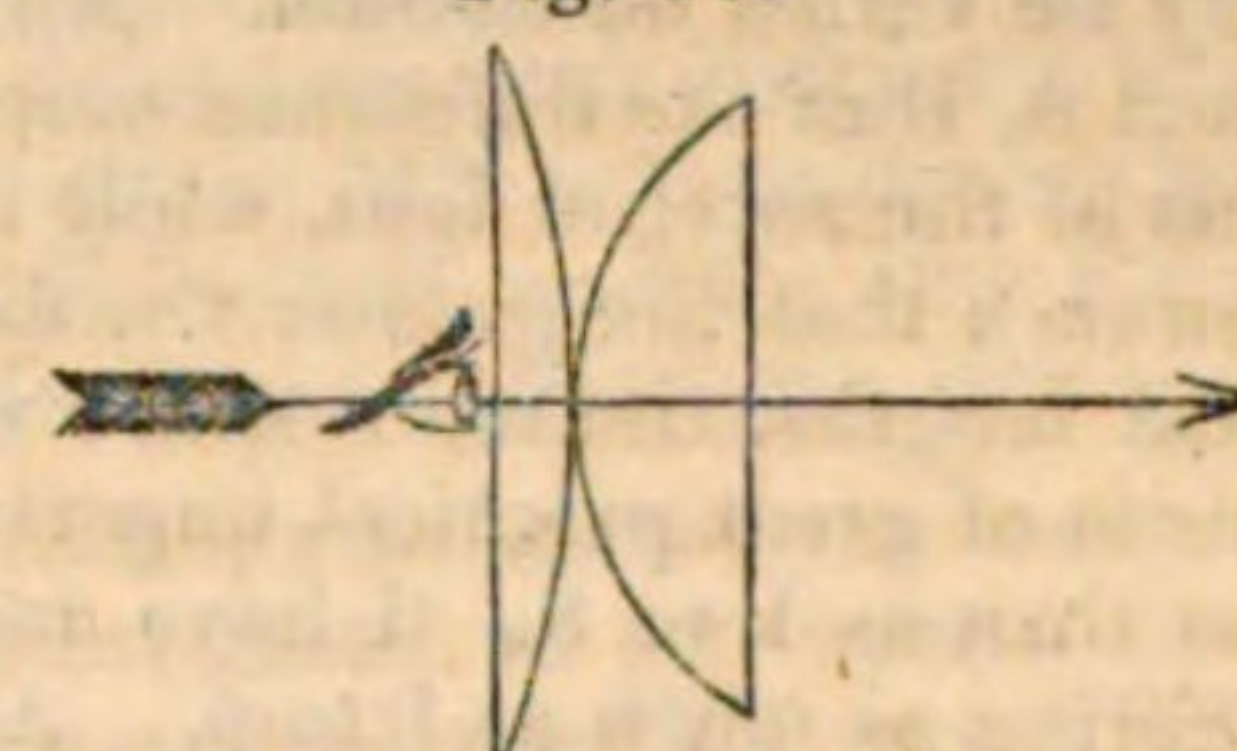
Fig. 15.



Plano-Convex Doublet.

A doublet of much simpler construction, and with its spherical aberration greatly diminished, has also been proposed by Sir John Herschel. It is represented in the annexed figure, and consists of two convex lenses of equal focal lengths, the convex sides being placed in contact, and the eye and object opposite the plane sides. In this case the aberration will be only 0.6028. But if we make the focal length of the first to that of the second as 1 to 2.3, the aberration will be reduced to 0.2481. In order to have an idea of the value of such a doublet, we shall give the series of aberrations for single lenses, as investigated by Sir John Herschel.

Fig. 16.



	Aberration.
Plano-convex, plane side first.....	4.2
Plano-convex, convex side first.....	10.81
Double convex.....	1.567
Best form of a single lens.....	1.00
Doublet of two equal plano-convex lenses.....	0.6028
Doublet of two plano-convex lenses with their focal lengths as 1 to 2.3.....	0.2481
Doublet of garnet, with suitable focal lengths.....	0.08

As these calculations are made for glass, the advantage of such a doublet made of garnet or sapphire must be much greater. In a garnet the minimum aberration takes place when the form of the lens differs very little from that of plano-convex; and as it is then to that of glass as 35 to 107, the aberration will be only about 0.08, or next to imperceptible.

Wollaston's Doublet.

The consideration of the Huygenian eye-piece for astronomical telescopes suggested to Dr Wollaston the probability that a similar combination should have a similar

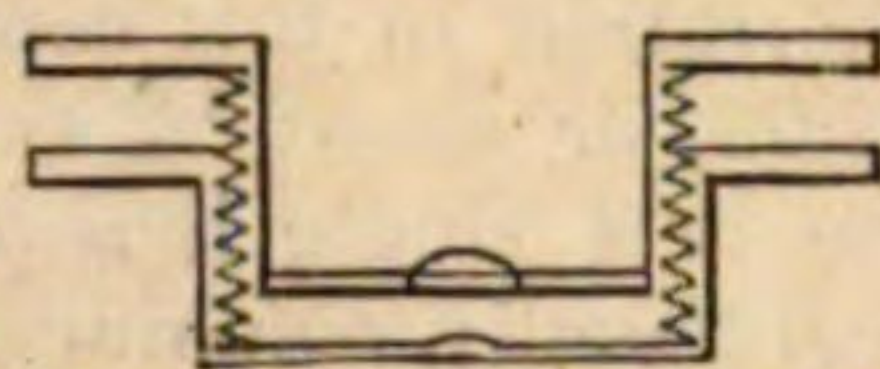
¹ Phil. Trans. 1821, p. 246-248.

² Microscopic Cabinet, p. 163.

Microscopic Doublets and Triplets.

advantage, of correcting both achromatic and spherical aberrations, if employed in an opposite direction as a microscope.¹ With this view, he took two plano-convex lenses, the ratio of whose focal lengths was as 3 to 1, and he placed them as in the annexed figure, so that the distance of their plane surfaces was from $1\frac{4}{10}$ to $1\frac{5}{10}$ of the focal length of the smallest. The plane sides of the lenses are towards the object. The advantage of the first lens having its plane side next the object is, as Dr Wollaston states, that if it should touch a fluid, the view is not only not impaired, but improved, whereas a double convex lens would require to be taken out and cleaned. The following excellent observations on this doublet are made by Pritchard.

Fig. 17.



Pritchard's observations on doublets.

"Having mounted some plano-convex lenses of the relative foci named by Dr Wollaston, in such a manner that the distances might be varied at pleasure, I was surprised to find, that after the doublet was adjusted *by trial*, so as to obtain the maximum of distinctness, the distance between the lenses did not accord either with the rule given by Huygens, or that of Dr Wollaston. Supposing that I had not got the combination intended by Dr Wollaston, I procured several doublets made by different artists, and to my astonishment found they agreed with my own, and therefore presumed the doctor was mistaken in the distance by the thickness of the lenses and the minuteness of the space between them. The distance which appeared to me essential to obtain the best effect, is the difference of the focal length of the two lenses, making a proper allowance for their thickness. The proportion of the foci of the two lenses may be varied *ad libitum*. All that is requisite in this respect is, that the difference must be greater than the thickness of the anterior lens, while it may be observed (in high powers), that the greater the difference between their two focal lengths, the more space will be left in front; and as this is of great practical importance, they should never be less than as 1 to 3. I have made some very good ones, differing as much as 1 to 6. Another advantage resulting from attending to this point is, that we do not lose so much magnifying power in such combinations as when the difference between the lenses is less.

"The delicacy and beauty with which these doublets exhibit the structure of tissues will justify my entering into some minute details respecting them. The following is necessary to ensure their goodness.

"First, The convex surface of each lens must be *truly spherical*. If this is not obtained, it will be in vain to procure a good doublet, however beautifully the lenses may be polished, or accurately adjusted. From this circumstance, I have found globules perform very well, providing they are free from air-bubbles, which, however, is rarely the case. It should be observed, that a slight scratch on their surface is trifling compared to air-bubbles; for the latter not only stop the light, but, by the reflection around the edges of each bubble, produce considerable fog or glare. Second, The distance between the lenses is the next point of importance; its adjustment is best accomplished by trial, mounting the lenses in such a manner that their distance can be varied at pleasure, and capable of being turned round, so as to adjust the centring. When this is obtained, they should be fixed so that their distance and position cannot be altered. This it is necessary to regard, as I have sometimes spent whole days in re-adjusting a doublet that had been separated to examine the lenses singly. Third, The stop or diaphragm, for limiting the aperture in these combinations, should be placed immediately behind the anterior lens. From the difference of the

situation of this stop in the various doublets I have examined, it will appear that their makers did not know that the field of view depended upon the plane of the stop. I have found, that when the stop is situated *close* behind the anterior lens, no other is required, and the field is enlarged without sensibly augmenting the aberration. On this account, the lenses of the finest doublet, when used singly with the same aperture as combined, has so much aberration and distortion that distinct vision cannot be obtained, even with the most rigid adjustment of the focus. From the difficulty of procuring a flat surface, some makers have worked the anterior surface of the lens next the object concave: these lenses do not possess any advantage in point of performance, not even to compensate for the loss of power from the negative side."

Mr Pritchard remarks, that when the lens next the object is a jewel, the performance of the doublet is improved; but that he has not observed any advantage when both lenses are gems. This must be a mistake; for lenses of any gem, that are superior to glass ones when acting singly, must, if suitably combined, be superior also when united. In proof of this, we have a garnet doublet before us, executed by Mr Blackie, the performance of which is quite remarkable. The lenses are made of Elie garnets, and their convex sides are placed towards each other. The radius of the smallest lens near the object is $\frac{1}{70}$ th (one seventieth) of an inch, and that of the other $\frac{1}{20}$ th (one twentieth) of an inch. Its magnifying power is very high, exceeding greatly that of the semi-jewel doublet made by Mr Pritchard, with a sapphire lens $\frac{1}{60}$ th (one sixtieth) of an inch focus, combined with a glass lens $\frac{1}{10}$ th (one tenth) of an inch focus.

In the experiments to which we have already referred on fluid lenses, Sir David Brewster has constructed doublets, one of the lenses of which is made of glass or a precious stone, and the other a fluid one, and he has been enabled to increase the power of any single lens by the addition of a fluid one, till the object touches the anterior surface of the object-lens. He has also made fluid spheres contracted in the middle, and fluid doublets in which the centring is effected by an infallible process.

Pritchard's Triplet.

Upon the same principle as the doublets, Mr Pritchard has constructed triplets, the third or posterior lens having a longer focal length than the two others. This combination requires much more precision in the adjustment, and more attention in the centring. Mr Pritchard remarks, that, "when perfected, they amply repay the pains bestowed upon them, in the accuracy with which they exhibit the most difficult lined objects, though it is to be regretted that neither these nor the doublets of deep power will show pleasantly cylindrical bodies of large diameter, such as a large mouse or bat's hair." Having long made use of one of Mr Pritchard's triplets, we can amply confirm the account which he has given of the excellence of this combination. Mr Blackie has executed for us a triplet, the centre lens of which is garnet, the posterior one of quartz, and the anterior one of flat glass. It is a very powerful combination, and performs admirably.

Sir David Brewster has made triplets in which two of the lenses are fluids and the third a solid, and some in which they are all fluids.

Single Achromatic Microscope.

In many of the doublets which we have already described, the chromatic aberration is partially, and sometimes greatly corrected, but still not to such a degree as to en-

Single achromatic microscope.

¹ Mr Coddington has shown that such a correction is impossible. (*Treatise on the Eye and Optical Instruments*, p. 55.)

Microscopic Doublets and Triplets.

Compound
Micro-
scopes.

Compound
Micro-
scopes.

title them to the name of achromatic. The great improvement which has taken place in the art of grinding and polishing small lenses, has enabled the optician to execute *double* and *triple* achromatic lenses, having a diameter so small as from $\frac{1}{4}$ th to $\frac{1}{16}$ th of an inch. Mr Pritchard has made them of the latter size with an angle of aperture of 65° . These lenses may be advantageously used where very high powers are not required, or when they cannot be applied, though it is usual to employ them as the object-glasses of compound microscopes, as we shall afterwards see.

Sir David Brewster has executed achromatic lenses both *double* and *triple*, by combining a fluid *concave* lens with one or two convex lenses of the precious stones or glass. When the lenses are *double*, the fluid lens is of course a meniscus in which the concavity predominates, as it is impossible to form a fluid lens doubly concave.

Single Reflecting Microscopes.

Single re-
flecting mi-
croscopes.

Single reflecting microscopes are not much in use. They consist of a concave metallic speculum of a short focal length, so that any minute body placed in its focus will be seen magnified. The form of the speculum should of course be parabolic. Such a microscope is principally useful for looking at one's own eye, or any part of it not far from the pupil. In these cases no image is formed, as the rays enter the eye parallel.

Fluid re-
flecting mi-
croscopes.

The following ingenious contrivance for a fluid reflecting microscope we owe to Mr Stephen Gray.¹ Having taken a small globule of quicksilver, and dissolved it in a menstruum of 10 parts of water and 1 of nitric acid (aqua fortis), he dipped the end of a stick in this solution, and rubbed with it the inner circle of the ring A, so as to give it a mercurial tincture. This ring is made of brass, and is about the 30th of an inch thick, having its mean diameter not exceeding $\frac{2}{3}$ ths of an inch. When the inner surface of the ring wetted with the solution has been wiped dry and laid upon a table, pour a drop of quicksilver within it, and when this drop is gently pressed with the ball of the finger, it will adhere to the ring, and when cleansed with a hare's foot will form a *convex* speculum. If the ring and speculum are now taken up and carried horizontally, and laid on the margin of the hollow cylinder B, the mercury will become a *concave* reflecting speculum, in consequence of its upper surface sinking down by gravity. The cylinder B rests upon a pillar with a screw on its outside, and supported by the base D. A stage, ECFG, may be moved up and down, so as to place the object, which is fixed at G, in the focus of the concave speculum.

Fig. 18.



CHAP. II.—ON COMPOUND MICROSCOPES.

On com-
pound mi-
croscopes.

A compound microscope is an instrument in which a distinct and enlarged image of an object is formed by an object-glass or a speculum, and this enlarged image again magnified by one or more eye-glasses.

There is every reason to believe, that the earliest compound microscopes, which were used by Jansen and Galileo, consisted of a convex lens for an object-glass, and a concave one for an eye-glass, like the telescope which was at that time in use.

Fontana in 1646 used *two* convex lenses; Dr Hooke

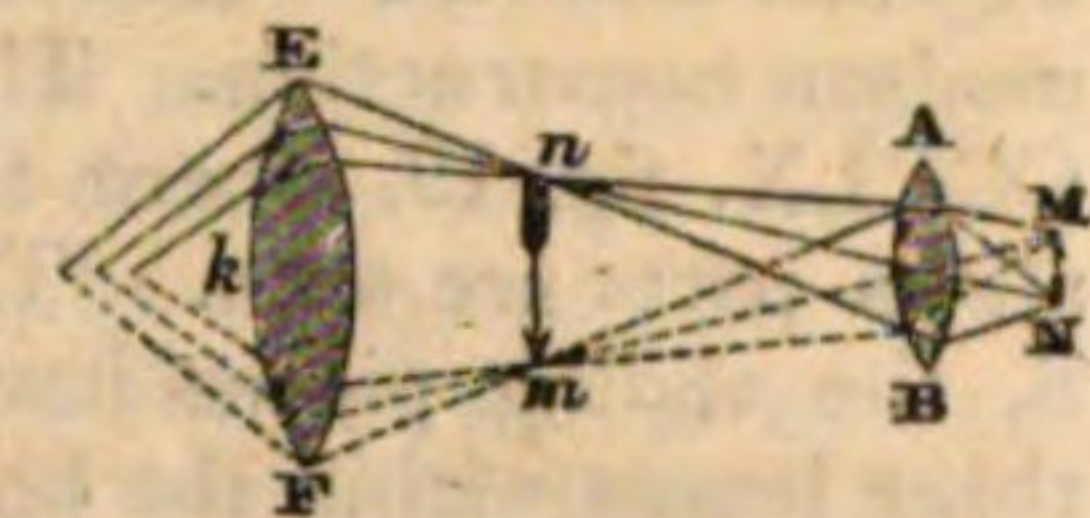
three, and Eustachio Divini *four*; the two next the eye being plano-convex, and placed in contact, with their convex sides towards each other, to give a high power and a large and flat field. In 1691 Philip Bonanni² used a compound microscope with three lenses, and added to it an illuminating apparatus with two lenses.

The reflecting compound microscope was first suggested by Sir Isaac Newton, and its construction varied and made more complex by Dr Barker and Dr Smith of Cambridge. The simple contrivance of Sir Isaac has in modern times been greatly improved by Amici, Potter, Tulley, Cuthbert, and Dr Goring, whose labours in improving the microscope have been indefatigable, and in the highest degree successful. An account of these improvements will be given in this chapter.

Compound Refracting Microscope.

The principle of the compound microscope with two lenses will be understood from the annexed figure, where MN is a minute object placed in the focus of the object-glass AB, or rather a little farther from it than its principal focus. An image of this object will be formed at *mn*, at some distance behind AB, the distance *nA* increasing as *AM* diminishes.

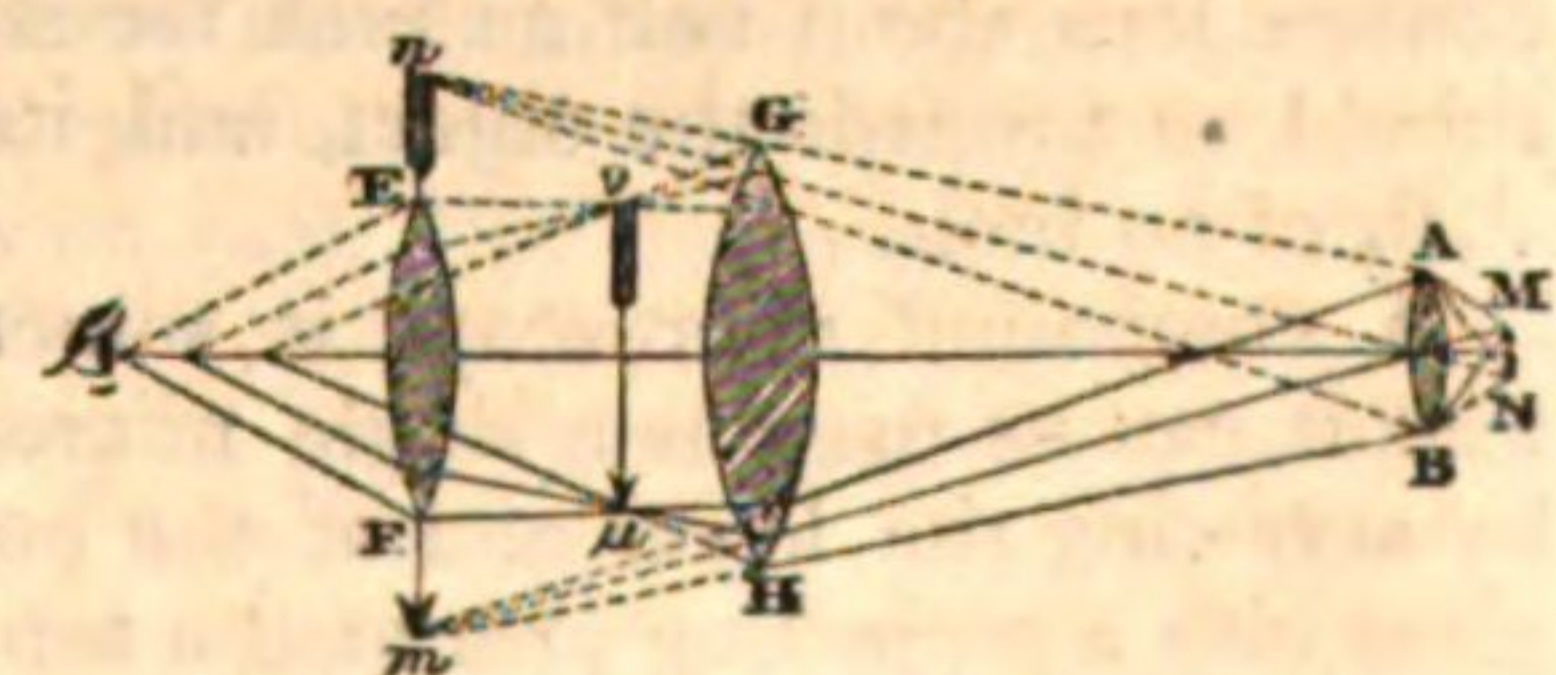
Fig. 19.



The size of the image *mn* will be to that of the object *MN* as *nA* is to *AM*, their distances from the lens *AB*. If we now view this magnified image *mn* through an eye-glass *EF*, so placed that *mn* is in its principal focus, we shall again magnify it in the inverse proportion of *En* to the distance at which the eye sees minute objects most distinctly, which is about five inches. The object *MN* is thus doubly magnified, so that if *nA* is six times *AM*, and the lens *EF* has a focal length of half an inch, the magnifying power will be $6 \times 5 \div \frac{1}{2} = 60$. While the lenses are the same, the magnifying power may be increased to any extent by increasing the distance between the lenses *EF* and *AB*, but the object becomes indistinct as the magnifying power increases, so that it is not advisable to make the distance *nA* more than five, six, or seven inches; or calling *f* the focal distance of the eye-glass, $D = AM$, $d = An$, and Δ the distance at which we see objects distinctly, then this magnifying power *M* will be $M = \frac{d}{D} \times \frac{\Delta}{f}$.

In this arrangement of lenses the field of view is small, and therefore we cannot see the whole of many objects at one view. In order to remedy this, a large lens, called the amplifying glass, is placed between the image and the object-glass, as shown in fig. 20, where *nm* is the image formed by *AB* alone; but in consequence of the interposition of *GH*, it is contracted into $\frac{1}{2}\mu$, and this contracted image is magnified by the eye-glass *EF*. In order to widen the field still farther, and make it flat, two plano-convex lenses have been placed at *E*, *F*, having their convex sides in contact. In order to find the magnifying power when the lens *GH* is used, we must multiply the magnifying power, as obtained by the preced-

Fig. 20.



¹ Phil. Trans. 1697, No. 228, p. 539.

² Observationes circa viventia, quæ in rebus non viventibus reperiuntur.

Compound
Micro-
scopes.

ing formula, by the quantity $\frac{L}{\phi}$, ϕ representing the focal

length of the lens GH and $L = \frac{\delta^2}{\delta - \phi} - d - f$, δ being the distance between the first and second glasses, and d the distance between the first and third glasses.

Dr Goring prefers the following method of finding the magnifying power of these microscopes. Measure the aperture of the object-glass and call it a , make $AM = f$, and having measured with a micrometer scale the diameter of the usual pencil of rays before they enter the eye, call it d ; then $a : f = d : F$, F being the focal length of a single lens having the same power as the compound microscope. But the magnifying power m of a lens F is $\frac{\Delta}{F}$.

Hence the magnifying power M of the compound microscope will be $M = \frac{\Delta a}{fa}$.

In accurate investigations with the microscope, the common compound refracting instrument above described is of little use, and has been superseded by better combinations. As it is, however, very serviceable for common purposes, we shall describe one of them of the most convenient and modern construction. This instrument is shown in Plate CCCLX. fig. 19, where the body of the microscope and all its parts are seen. They all slide on a triangular bar S , the sliding pieces having springs on one side. The three lenses within the body of the microscope are shown at EF , GH , AB , as in the last figure. The object MN is placed on a slider attached to the stage PQ . The reflector for illuminating the field is at R , being moved by a Hooke's universal joint at XX . A condensing lens is placed at C , for increasing the light reflected from the mirror R . The body of the instrument is adjusted to distinct vision of the object MN , by a rack and pinion working a triangular bar at right angles to the bar S . It is often thought preferable to move the stage towards the microscope, rather than the microscope towards the stage; but as the motion of the stage often disturbs animalculæ, and may derange the position of inanimate objects, the motion of the body of the microscope has many advantages. When the stage, however, is moveable, it is made to consist of three plates. The upper plate, which carries the slider-holder, is secured with a screw across the middle plate, which middle plate is carried across the lower stage-plate by a similar motion, but in a direction at right angles to the upper plate. By these movements the object can be placed in any position with regard to the axis of the fixed microscope, first by turning the one screw and then the other.

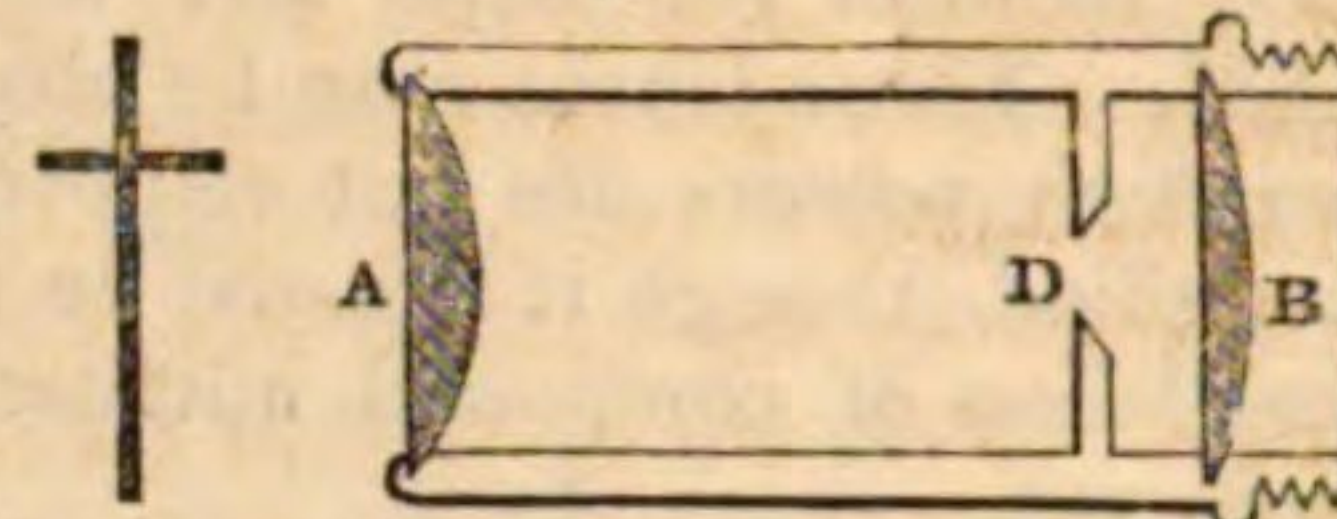
Some attention is requisite in adjusting the apertures of the object-glasses employed. The smaller they are, the less will be the spherical and chromatic aberration of the object-glass, but the less will be the light. When a plano-convex lens about half an inch focus is used, its plane side should be towards the object, and its aperture limited to $\frac{1}{4}$ th of an inch.

A compound microscope is sometimes so constructed that it can be used as a single microscope. This is done by screwing the lower end of the body round the object-glass into a projecting arm at the top of the stand. When the body is unscrewed and removed, a single lens or a doublet or triplet may be screwed into the same place, and the moveable stage, with the slider and object, brought near the single lens, just as if it had been the object-glass of a compound microscope.

Dr Goring's Improvement on the Object-Glass of the Compound Microscope.

When the compound microscope does not require to have a high power, a compound object-glass of two lenses may be advantageously employed. Dr Goring¹ has contrived the combination shown in the annexed figure, where A is a plano-convex lens with its flat side next the object, having its focal distance about one half or two thirds that of the plano or double convex lens B . A stop D is placed in the posterior focus of the object-glass A . Mr Pritchard remarks, that when the focal length of A "is not less than half an inch, this combination has been employed with considerable advantage, both as regards distinctness and aperture."

Fig. 21.

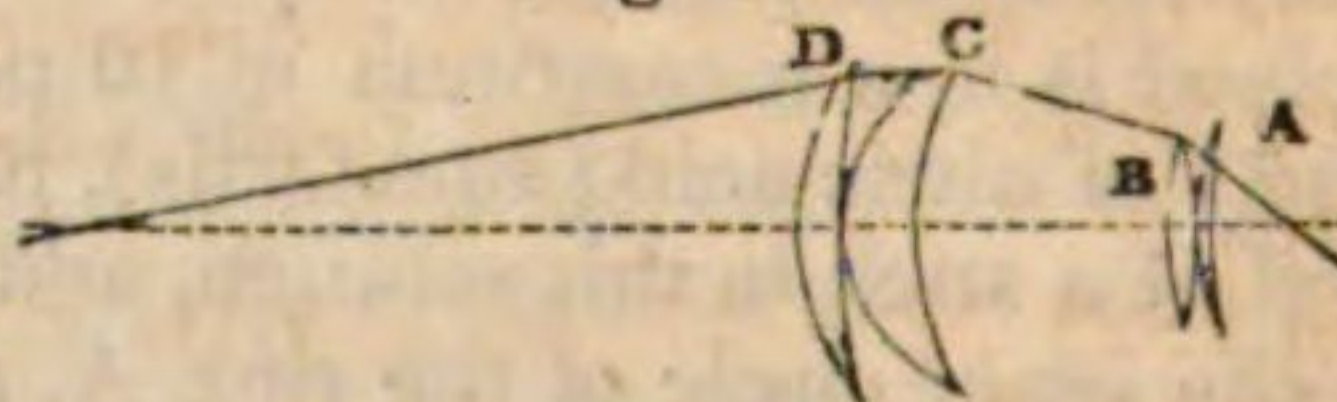


Compound
Micro-
scopes.
Dr Gor-
ing's ob-
ject-glass.

Mr Coddington's Improvement on the Eye-Glasses of the Compound Microscope.

The improvement suggested by Mr Coddington on the eye-pieces of compound microscopes is shown in Plate CCCLX. fig. 20. The object of the contrivance is to fulfil the condition proposed by Huygens in his excellent telescopic eye-piece, namely, to have the refraction of the pencils divided between the two lenses, and to produce the greatest possible flattening of the field. Mr Coddington found that the most proper form of the lenses was that shown in the annexed figure, where the two eye-glasses consist of a meniscus A next the eye, and a double equi-convex lens B , while the field-glass is composed of two meniscuses C , D . Mr Coddington, however, informs us, that he "found no sensible error arise from the substitution of plano-convex lenses for the meniscus-glasses, which are difficult and expensive to form." He remarks also, that theory indicates "a farther flattening of the field to be made by separating the eye-glasses a little, which requires the distance of the first eye-glass from the field-glass to be diminished by about half as much;" but he did not perceive any improvement arising from this alteration in practice, and therefore he does not recommend the change. The object-glass which Mr Coddington uses in this microscope is shown at o , and is the grooved sphere proposed by Sir David Brewster.

Fig. 22.



In his treatise on the eye and optical instruments, Mr Coddington has proposed a different combination for the eye-glasses and the field or amplifying-glass. Supposing the distance between the object-glass and field-glass to be 1 inch, and the focal length of the field and eye-glasses 1 inch each, and the distance between the field-glass and nearest eye-glass 1 inch, he finds the distance of the two eye-glasses to be $\frac{1}{2}$ th of an inch. He finds also, "that all indistinctness arising from the oblique refractions will be corrected when the field-glass is convexo-convex, nearly convexo-plane, the first eye-glass convexo-convex² (radii as 3 : 1), and the second eye-glass a meniscus³ (radii as 1 : 5)."

Taking another case, he supposes the distance of the object-glass from the field-glass to be 2 inches, and the eye-glasses to be in contact, as in fig. 22, then "it appears that for the achromatism we must have the distance between the field-glass and second eye-glass 1 inch."

¹ Quarterly Journal, vol. xvii. p. 202.

² The flattest side next the eye.

³ The most convex side next the eye.

Compound Microscopes. Then the field-glass must be convexo-plane nearly; the first eye-glass equi-convex, and the second eye-glass a meniscus with the radii as 1:5.

Dr Goring, who examined one of the instruments constructed on these principles, states, *that both the chromatic and spherical aberration of the objective part was wholly untouched, and that the eye-piece, consisting of four glasses, was achromatic.* He adds also, that nothing can surpass the beauty of the field of this microscope for extent of flatness. Now we think that Dr Goring has mistaken Mr Coddington, who never pretended to correct the spherical and chromatic aberration of the object-glass.¹ He considers the chromatic and spherical aberration of the grooved sphere, which is the object-glass he uses, as reduced to very small quantities, by leaving only a small channel in its axis for the passage of the rays. Whatever the residual aberration may be, Mr Coddington is not answerable for it, as his object was merely to make the other part of the microscope good, which, according to Dr Goring, he has succeeded in doing.

Compound Achromatic Microscope.

Compound achromatic microscope. Although the achromatic microscope has only recently come into use as an effective and superior instrument, yet it can scarcely be considered as a new instrument. Every person knew that an achromatic object-glass was most desirable in a compound microscope. So early as 1776 Euler proposed to employ them in compound microscopes; but so late as 1821 M. Biot considered their introduction as out of the question, from the impracticability of achromatizing lenses as small as those which the microscope requires.

M. Selligues. In 1823 M. Selligues and Dr Goring were both occupied with the subject, the former having employed MM. Chevalier, two excellent opticians in Paris, and the latter Mr Tulley, to execute small achromatic object-glasses. It is to M. Selligues, however, in so far as we can learn, that we are indebted for the new and happy idea of making the object-glass consist of *four* achromatic compound lenses, each consisting of two lenses. This idea is the actual source of the superiority of the achromatic microscopes; and in proof of this we may state, that Professor Amici, who had early been following out the old idea of a single achromatic object-glass, abandoned his attempts in 1815, but afterwards successfully resumed them by adopting M. Selligues' plan of the superposition of several object-glasses. In M. Selligues' instrument the focal length of each object-glass was 18 lines, its diameter 6 lines, and its thickness at the centre 6 lines. In that of Amici the focal length of each was about 6 lines, and MM. Chevalier have executed them having only 2 lines in focal length. More recently, however, Mr Pritchard has surpassed all these artists by making them of one sixteenth of an inch in focal length.

From this brief historical detail, we shall proceed to give a more minute account of the lenses executed by these different individuals, for which we are indebted to Mr Jackson Lister, whose able memoir on this subject is, as we shall see, one of the most valuable contributions to the science of the microscope that has for a long time appeared.

The achromatic object-glasses of M. Selligues' microscope made by MM. Chevalier, consisted of a plano-concave lens of flint glass, and a double convex one of crown or plate glass, with their inner curves cemented together by a mixture of mastic and turpentine, to remove the reflection

of the interior surfaces, and prevent the introduction of dampness. Four of these lenses, of from $1\frac{1}{2}$ to $1\frac{7}{8}$ of an inch in focal length, were made to screw before each other, so as to be used either all together, or any of them individually, in the usual manner, like the object-glasses of a compound microscope. The aberration of colour was thus corrected in a considerable degree, but the glasses were fixed in their places, with their convex sides towards the object, which is their worst position; and in consequence of this, the spherical aberration was enormous, and was distinctly seen, even with the small aperture to which it was necessary to reduce them.

Notwithstanding this defect, the grand idea of the combination was acquired; and M. Chevalier having observed the mistake committed by M. Selligues, made them of less focal length, and more achromatic; and turning the concave lens to the object, he produced in 1825 an instrument far above that of M. Selligues. His deepest glasses were four tenths of an inch in focal length; and in his first microscope two such compound lenses were combined for his highest power.

The date of Fraunhofer's achromatic microscopes is Fraunhofer not known. Many years ago the writer of this article ordered an achromatic object-glass from Fraunhofer for a large microscope, for the purpose of making a particular class of observations; but at that time he seems not to have made any compound lenses to be combined after the manner of Selligues. Mr Robert Brown² has a series of five such object-glasses, recently obtained from Utzschneider, whose focal lengths are from 1.8 to 0.43 of an inch.

When Professor Amici visited London in 1827, he brought with him some compound object-glasses, which performed very well; and Mr Lister has since learned from him that he has executed a combination of 2.7 lines in focal length, and 2.7 lines in aperture, which greatly excels the former.

Among the most successful improvers of the achromatic microscope we must rank Mr Jackson Lister, who has discovered some curious and valuable properties of these lenses that have escaped the notice of the most skilful analysts. Mr Lister has investigated the subject entirely as a matter of observation, and therefore his results are more likely to have a higher practical value.

Mr Lister takes as the basis of a microscopic object-glass two conditions, 1. that the flint glass shall be plano-concave; and, 2. that it shall be joined by some cement to the convex lens. The *first* condition obviates the risk of error in centring the two curves, and the *second* diminishes by nearly a half the loss of light from reflection, which is very great at the numerous surfaces of a combination of compound object-glasses.

Now Mr Lister has found that in every such compound lens which he has tried, whether the flint glass was Swiss or English, with a double convex of plate glass, which has been rendered achromatic by the form given to the outer curve of plate glass, the ratio between the refractive and dispersive powers has been such that its figure has been correct for rays issuing from some point in its axis not far from the principal focus on its plane side; and these rays either tend to a conjugate focus within the tube of the microscope, or emerge nearly parallel.

If AB represents such an object-glass, let us suppose that it is free from spherical and achromatic aberration for a ray FDEG radiating from F, then the angle of emergence GEH will be about three times as great as that of incidence FDI. If the radiant point is now made

¹ Treatise on the Eye and Optical Instruments, p. 58, 59, § 329.

² Phil. Trans. 1830, p. 188.

Compound Microscopes. to approach the lens, the angles of incidence and emergence will approach to equality, and the spherical aberration produced by the two will bear a less proportion to the opposing error of the single correcting curve ABC, and hence in this case the rays will be *over-corrected* for such a focus.

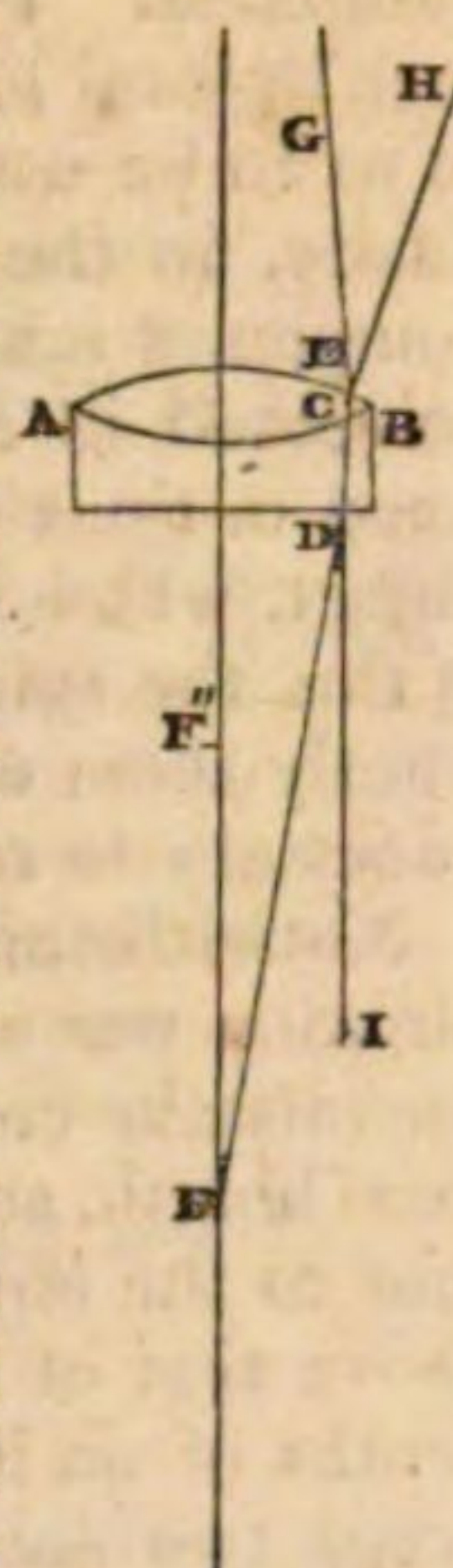
As F continues to approach the lens, the angle of incidence continuing to increase, it will exceed that of emergence, which has been in the mean time diminishing, so that the spherical aberration produced by the two outer surfaces will recover their original proportion. When F has reached this point F'' (at which the angle of incidence does not exceed that of emergence so much as it had at first come short of it), the rays will again be free from spherical aberration. If F'' still comes nearer the lens, or is carried beyond F in the opposite direction, the angle of incidence in the former case, or of emergence in the latter, becomes disproportionately effective, and in either case the aberration exceeds the correction, or the rays are *under-corrected*. Hence Mr Lister gives the following rule.

"That in general an achromatic object-glass, of which the inner surfaces are in contact, or nearly so, will have on one side of it two foci in its axis, for the rays proceeding from which the spherical aberration will be truly corrected at a moderate aperture; that for the space between these two points, its spherical aberration will be over-corrected, and beyond them either way, under-corrected."

Mr Lister found also, "that when the longer aplanatic focus is used, the marginal rays of a pencil not coincident with the axis of the glass are distorted, so that a coma is thrown outwards, while the contrary effect of a coma directed towards the centre of the field is produced by the rays from the shorter focus." These interesting results obviously furnish the means of destroying both aberrations in a large focal pencil, and of thus surmounting what has been hitherto the chief obstacle to the perfection of the microscope. And when it is considered that the curves of its diminutive object-glasses have required to be at least as exactly proportioned as those of a large telescope, to give the image of a bright point equally sharp and colourless, and that any change made to correct one aberration was liable to disturb the other, some idea may be formed of what the amount of that obstacle would have been. It will, however, be evident, that if any object-glass is but made achromatic, with its lenses truly worked and cemented, so that their axes coincide, it may with certainty be connected with another possessing the same requisites, and of suitable focus, so that the combination shall be free from spherical error also in the centre of its field.

For this the rays have only to be received by the front glass B, from its shorter aplanatic focus F, and transmitted in the direction of the larger correct pencil FA of the other glass A. It is desirable that the latter pencil should neither converge to a very short focus, nor be more than very slightly, if at all, divergent; and a little attention at first to the kind of glass used will keep it within this range, the denser flint being suited to the glasses of shorter focus and larger angle of aperture. If the two glasses which in the diagram are drawn as at some distance apart, are brought nearer together (if the place of A, for instance, is carried to the dotted figure), the rays transmitted by B in the direction of the larger aplanatic pencil of A, will

Fig. 23.



plainly be derived from some point (Z) more distant than F'', and lying between the aplanatic foci of B; therefore (according to what has been stated) this glass, and consequently the combination, will then be spherically over-corrected. If, on the other hand, the distance between A and B is increased, the opposite effects are of course produced.

In combining several glasses together, it is often convenient to transmit an under-corrected pencil from the front glass, and to counteract its error by over-correction in the middle one.

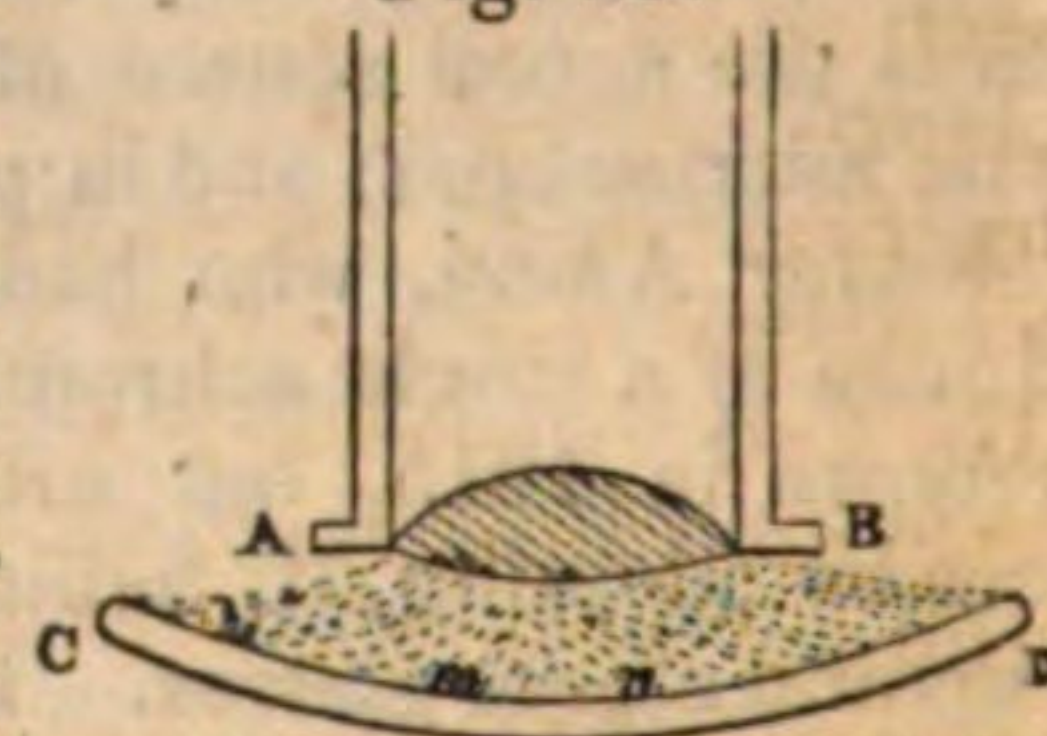
Slight errors in colour may, in the same manner, be destroyed by opposite ones; and on the principles described, we not only acquire fine correction for the central ray, but by the opposite effects at the two foci in the transverse pencil, all coma can be destroyed, and the whole field rendered beautifully flat and distinct.¹

Compound Achromatic Microscopes, with Solid and Fluid Lenses.

In 1812, a very simple method was employed by Sir David Brewster, for making both single and compound achromatic microscopes. Almost all objects are seen to the greatest advantage when immersed in a fluid, even the finest test objects, such as the scales of the Podura. Having placed the object on a piece of glass, he put above it a drop of an oil having a greater dispersive power than the single lens, or than the concave lens which formed the object-glass of the microscope. The lens was then made to touch the fluid, so that the surface of the fluid was as it were formed into a concave lens. Now if the radius of the outward surface of this lens was such as to correct the dispersion, we have here a perfect achromatic microscope, both simple and compound. The best way is to over-correct the colour of the plate-glass lens by the fluid, and then to reduce the dispersion of the fluid by mixing it with one of a less dispersive power. This will be understood from the annexed diagram, where AB is an unequally convex lens, the flattest side of which is plunged in the fluid mn, placed in a watch-glass CD. The object is placed at mn, and the dispersion of the concave surface of the fluid compensates that which is produced by the lens.

All errors of centring are here removed, and also the loss of light at the touching surfaces of solid lenses. If AB is a single microscope, the object mn will be placed in its principal focus, and the emergent parallel rays will enter the eye; but if it is the object-glass of a compound microscope, an image will be formed a few inches behind AB, by withdrawing AB a little from mn, or placing the object a little without its principal focus. We have already had occasion to describe an achromatic grooved sphere, but in the process of achromatizing it, the sphere loses in a very small degree its valuable property of refracting in the very same manner all the pencils that enter the eye. This property, however, may be preserved in the bird's-eye sphere by the achromatic method which we have now described. Let AB be the grooved sphere, and CD the watch-glass containing the fluid; it is obvious that every ray which passes through the centre of the sphere will enter and quit it perpendicularly, without suffering any refraction. The same mode of achromatizing the sphere AB may be adopted.

Fig. 25.



¹ Phil. Trans. 1830, p. 199.

Compound Microscopes. Achromatic grooved sphere. ed with a solid concentric concave lens ABCD of flint-glass or other substance, or the sphere may be placed between two such concentric lenses. The greater the dispersion of the flint-glass, the nearer must the outer surface CD approach to AB. By these means the grooved sphere may be rendered perfect, both as a single microscope and as the object-glass of a compound one.

System of solid and fluid achromatics. The principle above described may be applied to a system of object-glasses like those of Selligues' microscope. Let A, B, E be three convex lenses, so placed at the end of the tube of a compound microscope, that the highly dispersive fluid in the watch-glass CD will enter between the glasses A, B, and E. The concave lenses of fluid will over-correct the three lenses A, B, and E; but if a very deep curvature on the outside of A is not sufficient to compensate this over-correction, it may be effected by a suitable lens at F. If the three lenses are made of the precious stones, with a high refractive power and a low dispersive one, the concave fluid lenses will not over-correct them.

Fig. 26.

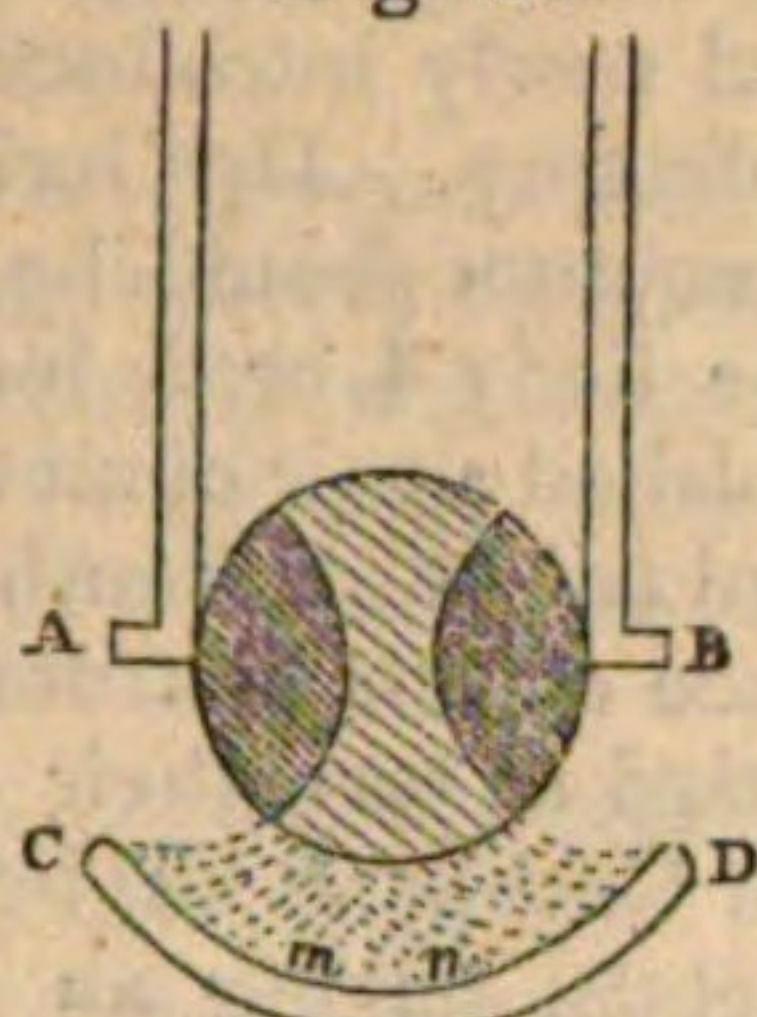
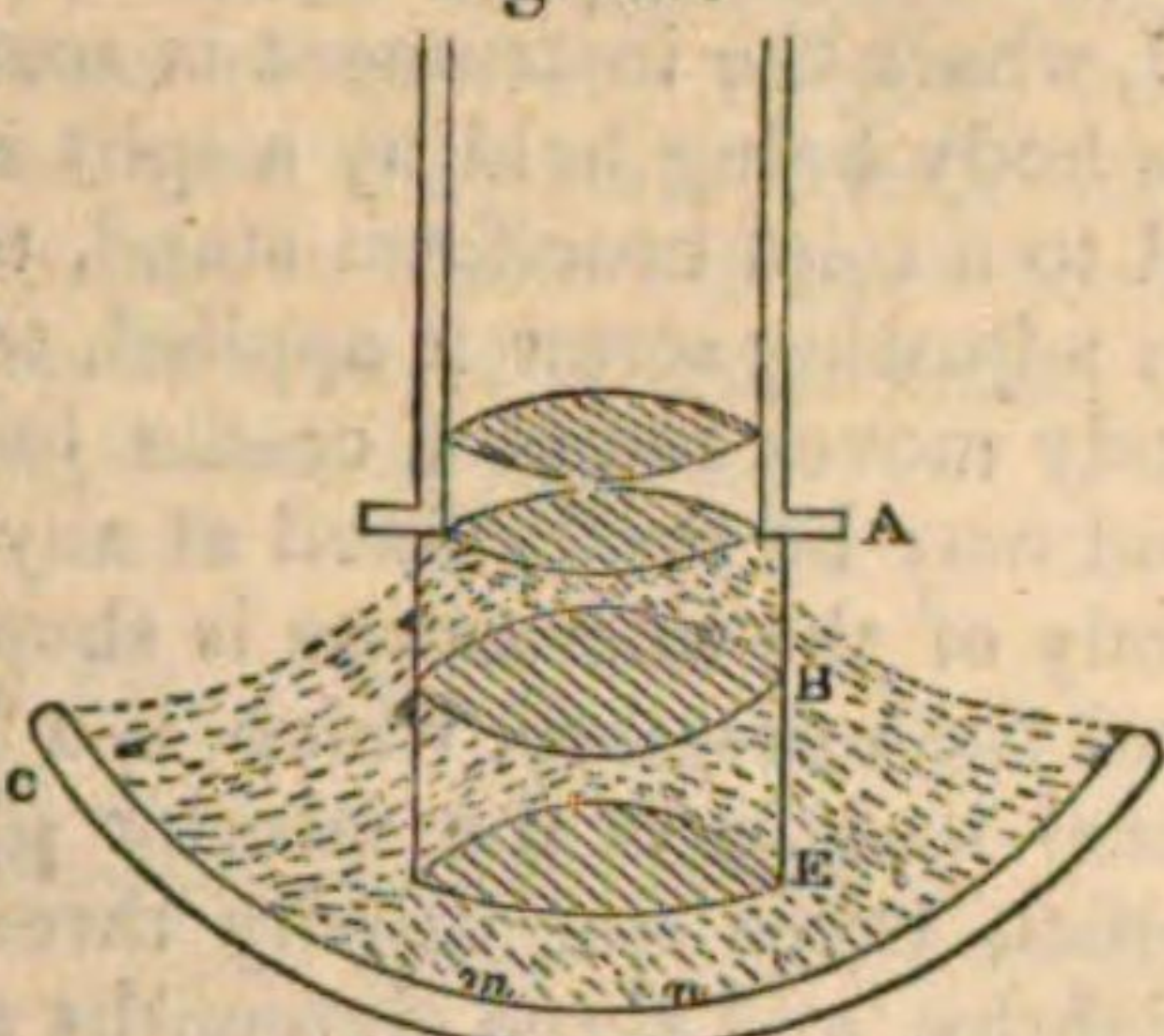


Fig. 27.



Description of Mr Pritchard's Compound Achromatic Microscope.

Pritchard's compound. This instrument is represented in Plate CCCLX. fig. 21, 22, 23, as fitted up by Mr Pritchard. All its parts are so distinctly shown in the figures, that they require no description, especially as the uses of most of the parts have been described in a former chapter. Fig. 21 is a perspective view of the instrument in its most convenient position for examining transparent objects by reflected light. The stops and condensing illuminator, which are seen under the stage, should be removed when particular objects are viewed. When test objects are to be viewed by direct light, the instrument can be turned round. Fig. 22 shows the position of the instrument for dissecting. The rest for supporting the hands is shown at a, and the large moveable stage at b. Fig. 23 shows the proper position of the instrument for viewing opaque objects by the concave reflector c. In front of c, the object is placed upon a black or white ground, according to its nature; and the light of the candle, collected and thrown upon the mirror c by the condensing lens, is again reflected by the mirror upon the object. Fig. 22 is an eye-piece; and fig. 23 represents an apparatus for holding a bottle to show aquatic plants and animals.

In Mr Pritchard's instrument the following are the dimensions and powers of the lenses for a complete microscope.

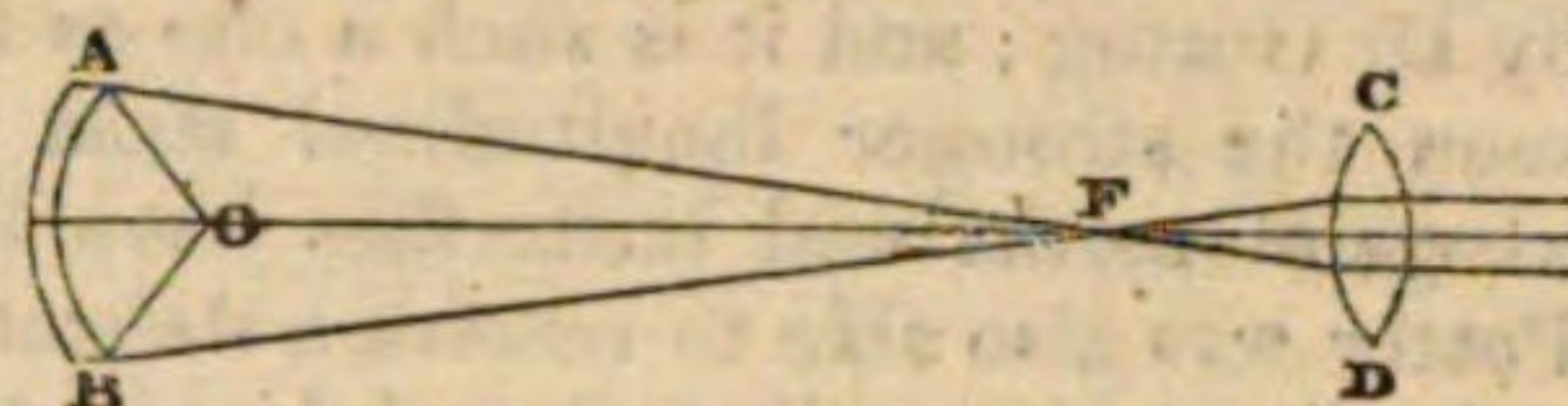
Sidereal Focal Length in Parts of an Inch.	Angle of Aperture.	Magnifying Powers in Diameters by a Standard of 5 Inches.
1	16°	60 to 100
$\frac{1}{2}$	21	100 to 360
$\frac{1}{4}$	42	240 to 500
$\frac{1}{8}$	55	500 to 1100
$\frac{1}{16}$	65	900 to 3000

Of these object-glasses, that whose focal length is $\frac{1}{4}$ th of an inch appears to be the most perfect and useful.

Compound Reflecting Microscopes.

Sir Isaac Newton seems to have been the first person who described a reflecting microscope. He communicated his plan to Oldenburg in 1679, as shown in the annexed diagram, where AB is a concave speculum, O the object, F the place where an image of it is formed, and CD an eye-glass for magnifying it. In another letter to Oldenburg, dated 11th July of the same year, he refers to another improvement on microscopes, which is to "illuminate the object in a darkened room, with the light of any convenient colour, not too much compounded; for by that means the microscope will, with distinctness, have a deeper charge and larger aperture, especially if its construction be such as I may hereafter describe." We are not aware that this idea was ever further developed by its author.¹

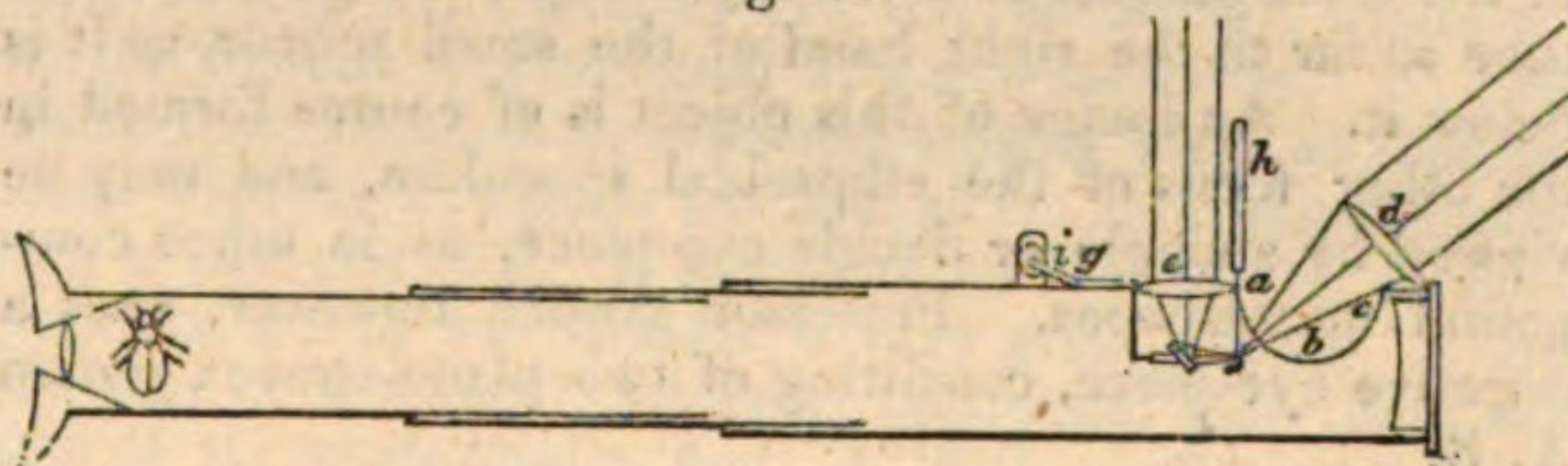
Fig. 28.



Mr Potter's Improvement upon it.

Mr Potter² has recently described "a new construction Mr Potter's improvement of Sir Isaac Newton's microscope," principally with the view of removing the difficulty of illuminating the object. His first construction was for opaque objects; and in order to improve upon it.

Fig. 29.



to illuminate them, he cut a large circular aperture *abc* in the tube, between the object and the speculum; but the light which fell on the sides of the tube occasioned a good deal of indistinctness in the field of view. This defect, however, was completely removed by lining all the lower parts of the tube with black velvet. Mr Potter found it advantageous to concentrate the light on these objects that required it, by a large lens at *d*. For transparent objects he applied a lens, as shown at *e*. Its convergent beam is reflected on the object placed at the end of the wire *a*, fixed to a handle *h*, by means of a small diagonal mirror in the axis of the tube, and inclined to this axis 45°. By this means a very strong light may be thrown through, and past the object. By means of moveable caps to cover the opening *abc*, and the lens *e*, all interference of foreign light is prevented; and without altering the position of the object, both methods of illumination may be successively adopted. Mr Potter attaches his objects to thin brass pins *a* stuck into wooden handles *h*, and these pins pass through a slit cut into a small piece of cork attached to the sliding piece *g*, which at the same time carries the lens *e* and the plane mirror, the whole of which are moved by the small arm connected to the crank, as at *i*. The adjustment of the object to the focus of the mirror is effected by turning a nut attached to the pivot on which the crank is fixed.

In the microscope used by Mr Potter, he employs a speculum one inch in diameter, with a focal length of $1\frac{1}{2}$ inch; and he generally employs a distance of from 12 to 14 inches between the object and the image.

This size of the speculum allows him to place an insect

¹ Brewster's Life of Sir Isaac Newton, p. 311.

² Edinburgh Journal of Science, Jan. 1832, No. XI. p. 61.

Compound or other object of $\frac{1}{4}$ th of an inch square in the tube, without any perceptible bad effect resulting from it.

Compound
Micro-
scopes.

When Mr Potter had adjusted the illuminators in the manner which we shall afterwards have occasion to describe, he "saw quite easily what are called the diagonal lines on the scale from the wing of the white cabbage butterfly, which has been proposed as a difficult test object by Dr Goring; and it is such a one as those who have only seen the stronger longitudinal striæ or scales from the wings of moths and butterflies have little idea of." Mr Potter was also able to resolve a delicate blue tissue in the web of a spider called the *clubiona atrox*, into its component fibres.

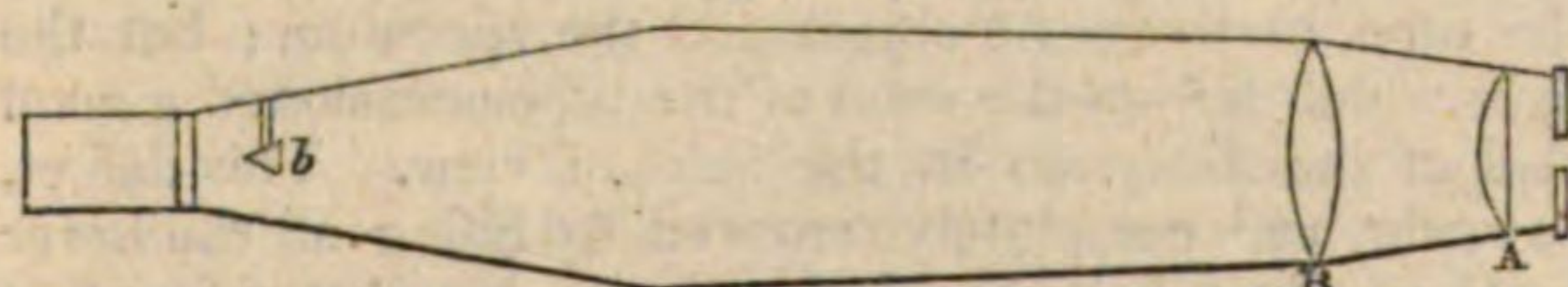
The great size of speculum used by Mr Potter arises from his being able to give all his specula a true ellipsoidal figure, so as to remove all spherical aberration.¹ We have in our possession two of Mr Potter's instruments, one of them with a *spherical* and the other with an *ellipsoidal* mirror. The quantity of light and the defining power of the latter are unusual in such instruments.

Amici's Reflecting Microscope.

Amici's re-
flecting mi-
croscope.

This instrument is shown in section in the annexed figure, where *a* is a small ellipsoidal speculum about 1 inch in diameter, and $2\frac{6}{10}$ ths in focal length. The object is placed on a stage *mn*, below the tube of the microscope, and the rays which issue from it fall upon a small speculum *b* inclined 45° to the axis of the ellipsoidal speculum, in the same manner as if the object had been placed in the tube as far to the right hand of the small mirror as it is below it. An image of this object is of course formed in the other focus of the ellipsoidal speculum, and may be viewed by a single or double eye-piece, as in other compound microscopes. Professor Amici, however, uses a negative eye-piece, consisting of two plano-convex lenses *A, B*.

Fig. 30.



The new and peculiar part of this instrument is the use of the small speculum, which allows the object to be placed without the tube, and illuminated with the utmost facility. Dr Goring, to whom science is indebted for the perfection of the reflecting microscope, remarks, that "the instrument was turned out of Professor Amici's hands in a rough and ineffective state, owing to the concave metal being of too long a focus and too small an angle of aperture, and the diagonal one (or small mirror *b*, which was half an inch in diameter) of too large a diameter, which caused it to intercept too large a quantity of light from the other, leaving only a narrow rim of reflexion to enter the retina, which occasioned a disagreeable nebulosity in the middle of the field of view, unless the eye-glass was of great depth."²

Dr Goring's Improved Reflecting Microscope.

Goring's
reflecting mi-
croscope.

Mr Cuthbert, an ingenious London optician, constructed one of Amici's instruments, the speculum having $1\frac{1}{2}$ inch of aperture, and a focal length of 3 inches, and the body of the microscope being about 1 foot long. Dr Goring and

he having tried it on the test objects which the doctor had newly introduced, found its performance quite unsatisfactory. Dr Goring, therefore, recommended that the speculum should be only half an inch in focal length, and the body 4 or 5 inches long. Mr Cuthbert accordingly finished a pair of metals six tenths of an inch in focal length, and only three tenths in diameter. The excellent performance of this instrument induced Dr Goring and Mr Pritchard to turn their attention to its improvement; and, as Mr Cuthbert³ has been able to execute perfectly ellipsoidal metals, having an aperture equal to their sidereal focal length, or 54° , and of so small a diameter as three tenths of an inch, they have been able to produce an instrument of a very perfect kind.

This microscope is represented in Plate CCCLXI. fig. 26, 27, where the instrument is seen to rest on a tubular pillar, its body being held by a split socket. The pillar is screwed to a solid cruciform stand, to one of the legs of which an adjusting screw is applied, to produce steadiness. The body moves round a cradle joint at the top of the pillar, and may be firmly fixed at any degree of inclination. The body of the microscope is shown at *a*, the eye-tube at *d*, and the eye-piece, which is a Huygenian one, at *e*. The focal lengths of the interior glasses of the eye-pieces, of which there are usually three, are three fourths, three eighths, and three sixteenths of an inch. The tube containing the specula is shown at *bc*. The triangular bar which carries the illuminating reflector, the stage, and the apparatus for adjustment, is shown at *f*, and is soldered to the neck of the body. The mirror *k* is plane on one side, and has a plaster of Paris surface on the other. The stage *l* is a combination of rack and screw work, wrought by two concentric milled heads at *m*. The smallest of these moves the object in the direction of the body, and the other in an opposite direction. The stage can be lifted out of the triangular socket *q*, which carries the adjusting screw *i* for obtaining distinct vision, and the clamping screw *h*.

When the body and stand are used for a compound achromatic microscope, a tube, shown in fig. 27, and containing the compound object-glasses below it, increasing in diameter from the object, is screwed into the body at *b*, in place of the tube *bc*. A rectangular prism, shown in dotted lines, reflects the pencils that pass through the object-glasses along the axis of the tube *bc* to the eye-piece *e*.

The following sets of metals are made for the reflecting microscope.

No.	Solar Focus.	Angle of Aperture.	Distance between Object and side of the Tube.
1.....	2 inches.	$13\frac{3}{4}^\circ$	$\frac{1}{2}$ inch.
2.....	1	$18\frac{1}{5}^\circ$	$\frac{1}{3}$
3.....	$\frac{6}{10}$	$27\frac{1}{2}^\circ$	$\frac{1}{10}$
4.....	$\frac{4}{10}$	$36\frac{1}{2}^\circ$	$\frac{1}{20}$
5.....	$\frac{3}{10}$	$41\frac{1}{4}^\circ$	almost 0
6.....	$\frac{3}{10}$	55	

The metals No. 1, 2, and 3 are those most useful for examining opaque objects. No. 3 is excellent also for all kinds of transparent objects. No. 5 can scarcely be used for opaque objects, as it leaves almost no space between the tube and the object for allowing the latter to be illuminated. No. 6 cannot be used at all for opaque objects, but is especially intended for the most difficult class of transparent test objects.

¹ The process by which he does this is fully described in the Edinburgh Journal of Science, No. 12, new series.

² Goring and Pritchard's *Micrographia*, p. 23.

³ The process by which Mr Cuthbert is able to accomplish this difficult task is similar to that by which he gives truly hyperbolic figures to the mirrors of small Gregorian telescopes, with three inches of aperture and five inches of focal length.

Compound
Micro-
scopes.

Compound
Micro-
scopes.
Smith's re-
flecting mi-
croscope.

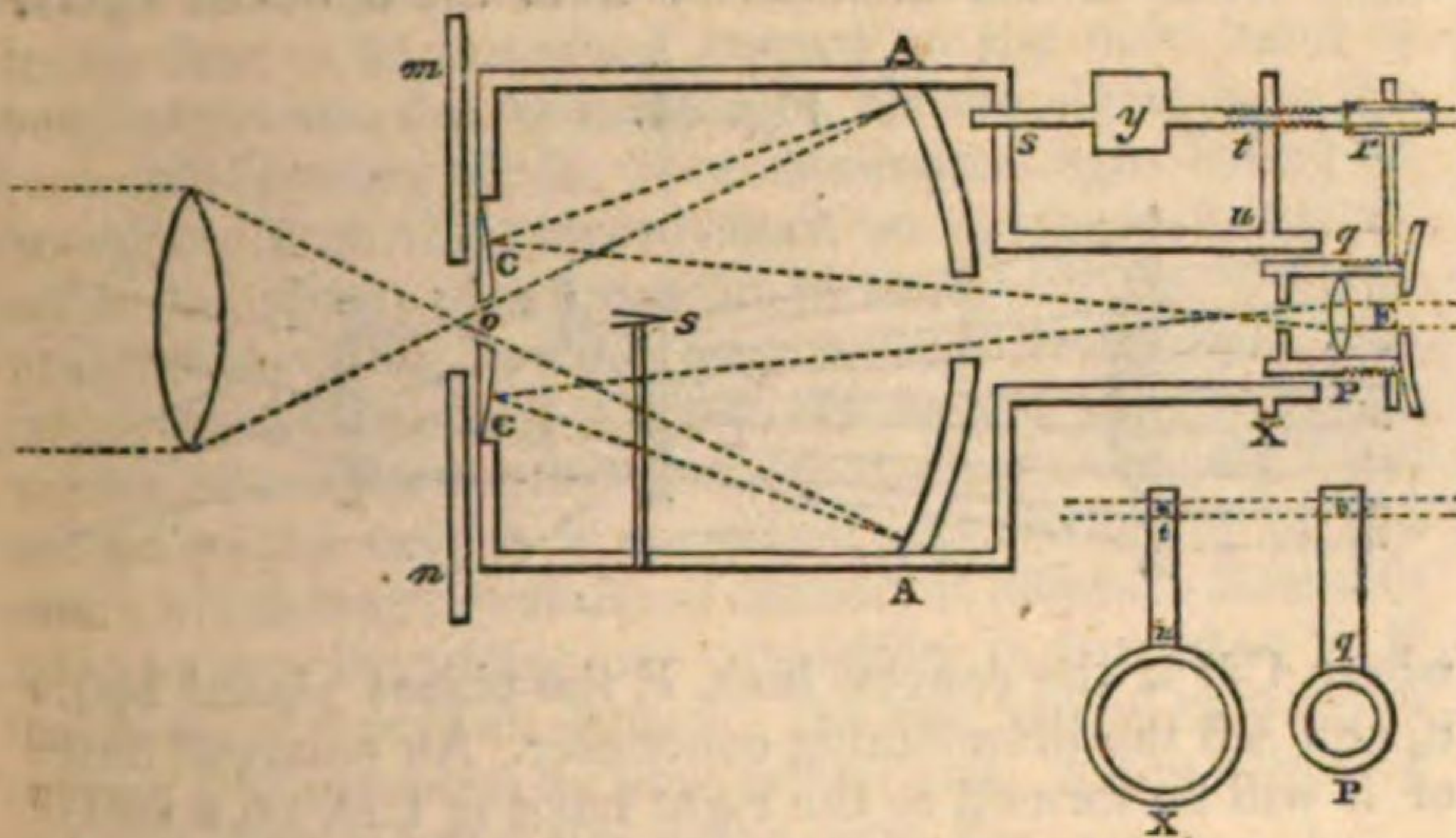
Dr Smith's Reflecting Microscope.

Having constructed one of Sir Isaac Newton's microscopes in 1738, Dr Smith of Cambridge observed that the colours of objects were much more beautiful and natural than in refracting microscopes. He found that objects were very distinct and sufficiently light when the microscope had the following dimensions:—

Focal length of the speculum..... $2\frac{1}{2}$ inches.
Diameter of ditto 1
Focal length of the plano-convex eye-glass..... $2\frac{1}{3}$
Ratio of the distance of the object from the focus of the speculum to the focal distance of the speculum 1 to 19.

Finding that, in order to obtain a high magnifying power, the speculum required to be very concave and small, he contrived another microscope with two reflecting spherical surfaces of any size, but so related to each other that the second reflexion should correct the aberration of the first. This instrument is shown in fig. 31.

Fig. 31.



Dr Smith's microscope is shown in fig. 31, where AA is a concave spherical speculum, having its polished convex surface inwards. The rays from an object *o* placed in the slider *mn* will be reflected from the concave speculum AA upon the convex CC, and will have a distinct and magnified image of it formed before the convex eye-glass E, by which it will be magnified still more. This instrument, in short, is nothing more than the Cassegrainian telescope converted into a microscope, with this difference only, that in the telescope distinct vision is obtained by moving the convex mirror, whereas in the microscope it is obtained by a motion of the eye-glass. Dr Smith constructed one of these microscopes, which he found to perform "nearly as well, in all respects, as the very best refracting microscopes;" and the writer of this article has one of them now before him, which performs wonderfully well, though both the specula have their polish considerably injured. It shows the lines on some of the test objects with very considerable sharpness.

The following are the dimensions, &c. of Dr Smith's reflecting mirror, as given by himself:—

Focal length of both specula.....1.0000
Distance of the centres of both specula.....1.6558
Distance of the image from the centre of the concave speculum.....1.1337
Focal length of the eye-glass.....0.1407
Distance of the eye behind the eye-glass.....0.1479
Diameter of the eye-hole.....0.0190
Distance of the object from the centre of the convex speculum.....0.0626
Length of the concave speculum..... $15^{\circ} 49'$
Arch of the convex speculum..... $4^{\circ} 50' 49''$
Distance of the stop *s* from the object.....0.4545
Diameter of the stop *s*.....0.038

Diameter of the hole in the concave speculum.....0.143
Diameter of the hole in the convex speculum.....0.049
Magnifying power, the focal length, &c. of the eye being 8 inches.....300 times.

The dimensions of the instrument in our possession is very different:

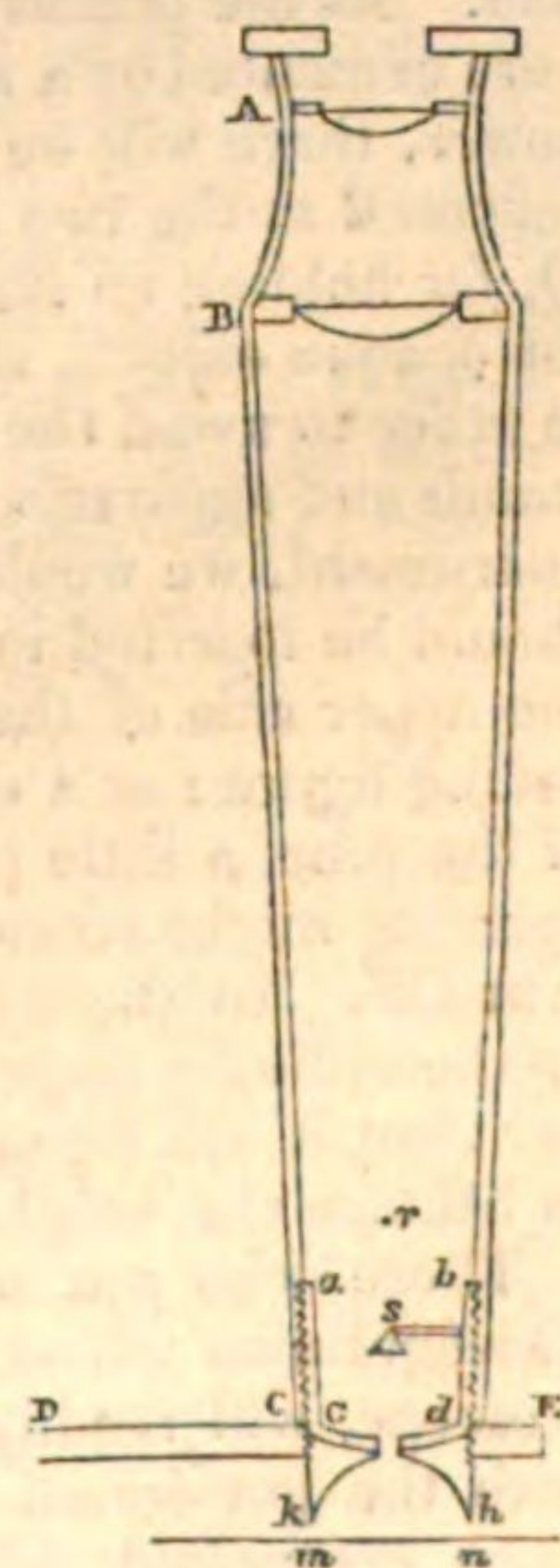
Diameter of the concave speculum.....2.17 inches.
Focal length.....2.17
Diameter of the hole in it.....0.376
Diameter of the convex speculum.....1.03
Diameter of hole in it.....0.10
Diameter of stop.....0.13
Distance of stop from hole in convex speculum.....0.67
Distance of specula.....3.80
Focal length of doubly convex eye-glass.....0.17

Sir David Brewster's Reflecting Microscope.

Notwithstanding the excellence of Professor Amici's Sir David microscope, as constructed with Dr Goring's improved reflecting ments and with Mr Cuthbert's specula, we are quite convinced that it does not owe these advantages to the peculiarity in its construction which constitutes it a different instrument from Newton's. This peculiarity is in our opinion a disadvantage, and we consider the instrument as recommended solely by its possessing an ellipsoidal speculum, with a large angle of aperture. The only advantage which can be ascribed to Amici's instrument is a more convenient mode of illumination, though not much more so than Mr Potter's; but this advantage, whatever be its amount, is purchased at great sacrifices. 1. The whole instrument is an awkward-looking piece of mechanism, with its triangular bar and all its appendages dangling at one end of it. 2. It cannot be used in the vertical position, which we consider a very great defect. 3. By the use of the small reflecting speculum, *more than one half of the whole light is lost*. 4. With small concave specula, such as those $\frac{5}{10}$ ths of an inch in diameter, opaque objects cannot be illuminated, as stated by Dr Goring.

The construction which has been proposed by Sir David Brewster to remedy most of these defects is shown in the annexed figure, where ABC is the body of the instrument, which screws at its lower end C into the horizontal projecting arm DE of the stand, either of the achromatic microscope or the single microscope, so that we get rid of all trouble about the objects placed at *mn*, and their mode of illumination, as every thing concerning them is the same as in other microscopes. This, we must say, is a great advantage; for neither naturalists nor amateurs are disposed to purchase and use two sets of the extended apparatus necessary for holding, moving, and illuminating microscopic objects. At the lower end C of the body, exactly where the object-glasses of the compound and achromatic object-lenses are placed, is a small tube *abcd*, at the lower end of which is placed the concave speculum *cd*, perforated with a very small hole at its centre, and with its concave surface upwards. Above it is the plane speculum *s*, fixed by a slender arm to the side *bd* of the small tube, and having its diameter a little greater than the perforation in the speculum *cd*. This little tube *abcd* screws into the arm DE, as if it were a microscopic doublet or single lens; and the body ABC may

Fig. 32.

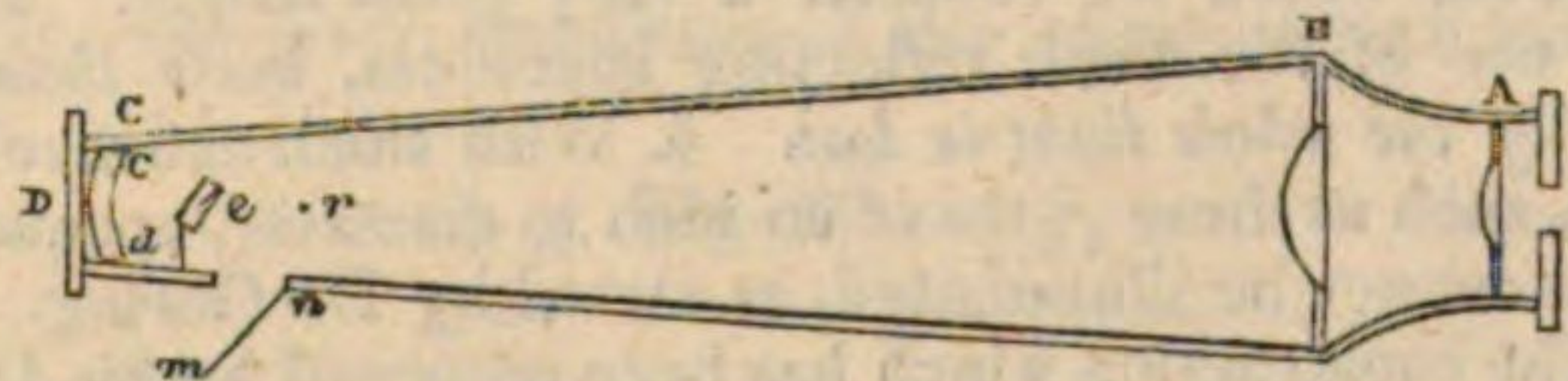


Compound Microscopes. either screw upon the outside of this tube, or, what is better, upon a stronger piece of tube forming part of the arm DE. A concave illuminating reflector *hh*, for opaque objects, may screw on the back of the speculum *cd*, or that speculum may be made thick, and ground and polished on both sides, so that while one side magnifies the objects, the other illuminates them.

It is obvious, that rays proceeding from an object at *mn* will be reflected from the plane speculum *e*, upon the concave speculum *cd*, exactly as if the objects were placed at *r*, as far above *e* as *mn* is below it, and an image of it would be formed in the other focus of the ellipsoid, *r* being the one focus, if the rays were not intercepted by the eye-piece AB, by which the image is farther magnified. By this mode of construction, the whole of the reflecting microscope, in place of having a separate stand and separate apparatus costing a large sum of money, is comprehended in the little tube *abcd*, and may be considered as a reflecting object-speculum, forming part of a general microscope, furnished with single lenses, doublets, and compound achromatics.

By the means now described are removed all the defects which we enumerated as belonging to Amici's combination, except the *third*, which is one of such importance that it is of consequence to consider how far it is capable of being remedied. Sir David Brewster has proposed to get rid of this loss of light by placing the object *mn*, as in Amici's instrument, outside of the tube, but inclined to its axis, and refracting its rays upon the speculum *cd*, by means of an achromatic prism *e*, in a manner analogous to his method of producing a similar effect in the Newtonian telescope.¹ The faces of this prism are equally

Fig. 33.



inclined to the axis of the microscope and the axis of the pencil issuing from the point of the object under examination. As the prisms of plate and flint glass which compose *e* are cemented by a substance of nearly the same refractive power, there will be no farther loss of light than what is reflected at the two surfaces. A socket may be placed at D, for holding an illuminating lens, or the little apparatus for opaque objects, shown in Plate CCCLXI. fig. 27. But in order to avoid the encumbrance and expense of separate stands and apparatus for this, as well as Amici's form of the instrument, we would propose that a strong piece of tube should be inserted in the opening, above *mn*, to screw into the upper side of the projecting arm, as shown in the preceding figure; or a solid screw attached to the upper side of the tube, a little to the right hand of C, and above the opening, might screw into the lower end of the projecting arm DF. In these cases the object at *mn* will be placed on the ordinary stage, and illuminated in the common manner; but it will be necessary to have a counterpoise at D, to balance the weight of the body ABC.

Those who are acquainted with the principle of the Cassegrainian telescope, and of Dr Smith's compound microscope, will readily see that the reflecting microscope, with the perforated speculum, may be converted into a more compound reflector, analogous to Dr Smith's, by making the little speculum *e*, fig. 33, convex, the figures of *d* and *e* being made hyperboloids.

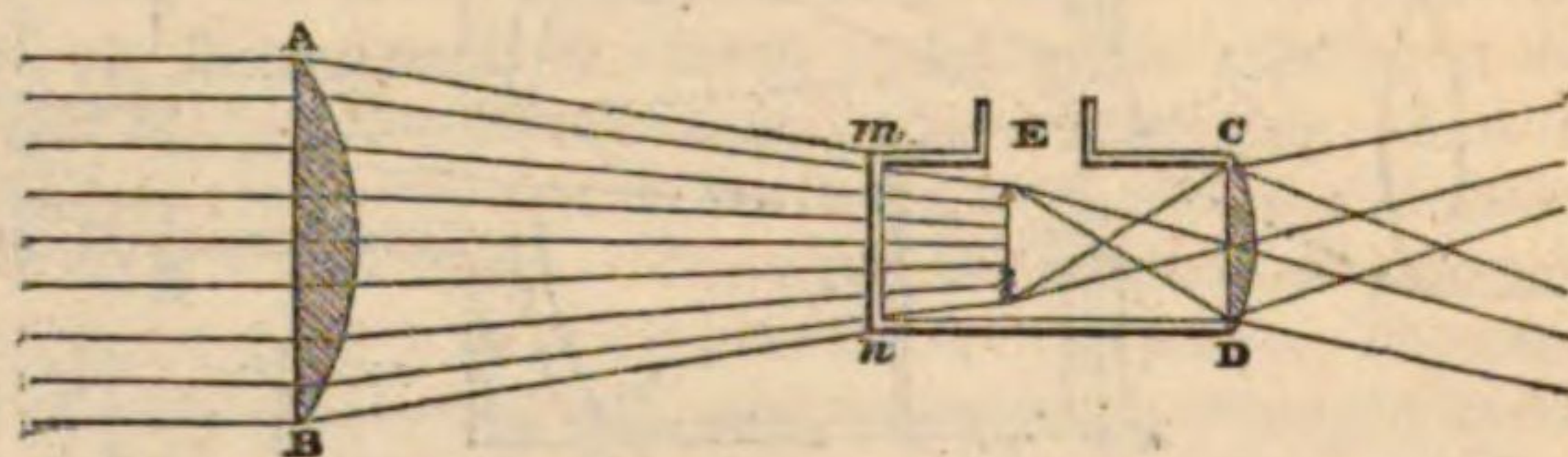
CHAP. III.—ON SOLAR AND OXYHYDROGEN MICROSCOPES.

The solar microscope is a well-known popular instrument, for exhibiting on a white screen in a dark chamber, magnified images of minute objects, illuminated by the condensed light of the sun. As the sun cannot often be commanded in our climate, this instrument may be considered as having fallen into disuse; but the discovery of the lime-ball light by Mr Drummond amply supplies the place of the great luminary, in so far as the microscope is concerned. The instrument has accordingly been revived under the name of the oxyhydrogen microscope, and is now a favourite public exhibition.

The solar microscope was proposed by Dr Lieberkhun in 1738; and early in 1739, when he paid a visit to London, he exhibited an instrument of his own construction to several members of the Royal Society, and to Mr Cuff, Mr Adams, and other London opticians.

This microscope is nothing more than a convex lens, in front of which, a little farther from it than its principal focus, is placed a microscopic object, the rays of the sun being reflected in a horizontal line, and condensed by a lens. This will be understood from the annexed figure,

Fig. 34.



where CD is the convex lens, E the object placed before it, and AB the illuminating condenser. An enlarged image of E will be formed to the right hand of CD, on a wall or screen, and the size of the enlarged image will be to that of the object as the distance of CD from the screen or wall is to CE, the distance of the object from the lens. Dr Lieberkhun's solar microscope had no mirror for reflecting the sun's rays into the tube, so that it could only be used a few hours, when the tube could be conveniently pointed to the sun. The improvement of adding a mirror was made by Mr Cuff, who constructed the instrument in a very superior manner.² Dr Lieberkhun subsequently fitted up the solar microscope to show opaque objects; but the method which he employed is not known. Since the time of Mr Cuff, the solar microscope has undergone many improvements. Mr Benjamin Martin added greatly to the value of this instrument, by fitting it up both for opaque and transparent objects, in the manner shown in Plate CCCLXI. figs. 28 and 29. In fig. 28 it is shown as fitted up for opaque objects. The body ABCDEF has the part ABCD of a conical, and the part CDEF of a tubular form. A large convex lens, corresponding with AB, in fig. 34 is placed at AB, at the end of the conical tube ABCD, which screws into the square plate QR, which is fastened to a window-shutter opposite a hole of at least the size of the lens AB, by means of the screw *e*, *d*. Upon the square plate QR there is a moveable circular plate *abc*. To this circular plate is attached the silvered glass mirror NOP, placed in a brass frame, which moves round a joint PP, and which may be placed in any position with regard to the sun, so as to reflect his rays into the tube ABCD by means of rack-work and pinions at Q and R. The pinion Q moves the circular plate *abc* (to which the mirror NOP is fixed) in a plane perpendicular to the horizon, while the nut R gives it a motion in an opposite plane. The

¹ Treatise on Optics, Lardner's Cabinet Cyclopædia, p. 354.

² See Baker on the Microscope, vol. i. p. 22.

Solar and Oxyhydro-gen Microscopes. light introduced by this mirror falls upon the lens AB, which throws it in a condensed state upon any object in the tube. But before it reaches the opaque object, it is received by a mirror M, placed in the box HILX, which reflects the condensed light back upon the face of the object E, fig. 34, next to the lens CD, fig. 34. This mirror is adjusted to a proper angle by the screw S.

Above the body ABEF is seen the part fVK which carries the sliders or objects, and the object-glass or lens CD, fig. 34. The tube K slides within the tube V, and V again slides into the box HILX. These tubes carry each a magnifying lens. The inner tube K is sometimes taken out of the other V, seen within the box, and used alone. The sliders and objects are introduced into a slit or opening at H. The brass plate to the left of H is fixed to a tube h, by means of a spiral wire within the tube, which presses the plate against the side of the box HILX, so that the sliders, when placed in the opening, are pressed against the side of the box.

In using this microscope, the sun's rays are first made to pass along the tube ABCD, by the nuts Q and R. The box for opaque objects, HILX, is then slid by its tube G into the tube EF. The slider containing the object, having its face to be examined turned to the right hand, is then pushed into the opening at H, till the object is in the centre of the tubes V, K. The condensed light falling on the mirror M is then thrown back on the face of the object in the slider, and the door *hi* shut. Upon a white paper screen or cloth, from *four* to *eight* feet square, and placed at the distance of from six to ten feet from the window, the observer, in the room made thoroughly dark, will see on the screen a magnified representation of the object, which may be rendered distinct at different distances of the screen, by pulling out or pushing in the tubes V, K containing the convex lenses. As the sun is constantly moving, its rays must be kept in the axis of the tubes by now and then turning the nuts Q and R.

When the microscope is to be used for transparent objects, the box HILX, with its tube G, and other appendages, is removed, and the apparatus shown in fig. 31 substituted for it. This is done by sliding the tube Y of fig. 31 into the tube EF of fig. 30. A slider containing the magnifying lens is then slipped through the opening at *n*, and a second condenser may or may not be inserted in the opening at *h*. The slider with the object is then placed in the opening *m*, and when its magnified picture falls upon the screen, it is adjusted to distinctness by turning the milled nut O.

The picture formed by a solar microscope being in Dr Robison's opinion "generally so indistinct that it is fit only for amusing ladies," he proposed to use as an object-glass the achromatic eye-piece of four lenses, constructed by Mr Ramsden for telescopes. Having made the experiment, he found the image "perfectly sharp," and recommended this application "to the artists, as a valuable article of their trade."

A much simpler method, however, of correcting the defects of the microscope, is to use compound achromatic lenses, which were first suggested by Mr Benjamin Martin.

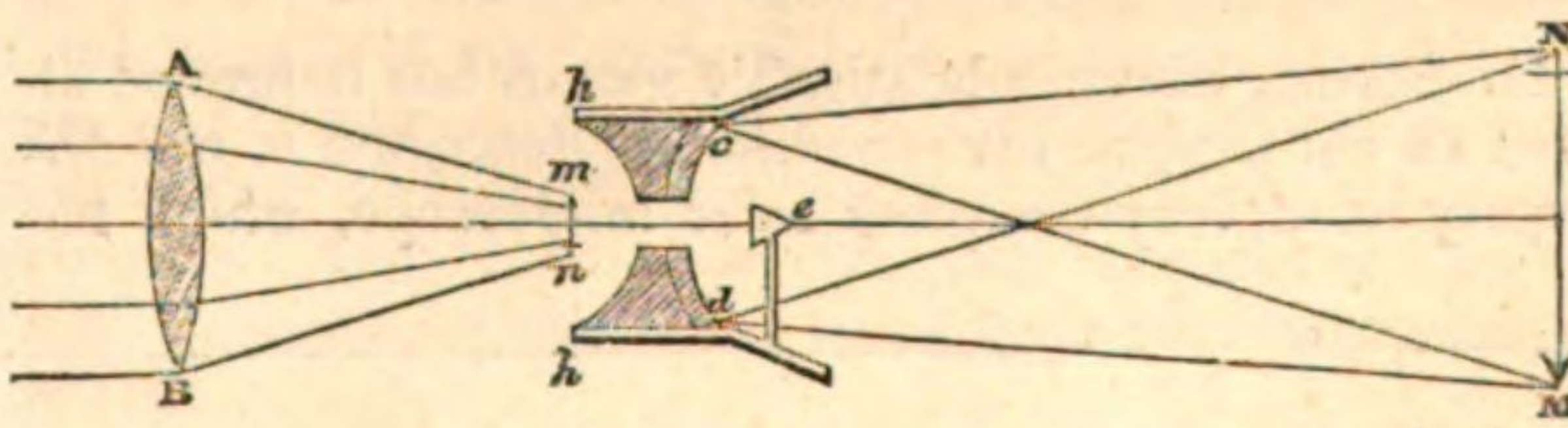
Another mode of improving the instrument was proposed in 1812 by Sir David Brewster,¹ who has described a new solar microscope, which can be rendered achromatic. The method of doing this is shown in the diagram, fig. 34, where AB is the condensing lens, and

CD the object-glass, cemented firmly into one end of a tube *mCDn*, which has a tubular opening at E, while the other end of the tube has a circular piece of parallel glass cemented upon it. The tube *mCDn* is then filled with water, or any other fluid; and the object, when placed upon a slider, or held in a pair of forceps, is introduced at the opening E into the fluid. The mechanism for producing these effects is easily conceived. By the instrument thus constructed, imperfectly opaque and corrugated objects, rendered transparent, and extended by the fluid medium, may be examined in this microscope, though incapable of being used in any other. Objects may be even dissected in the aqueous tube. Nay, objects preserved in spirits might be exhibited by immersing the bottle, if it is small, in the trough or tube *mCDn*.²

But the most important purpose effected by this form of the instrument is, that it can be rendered perfectly achromatic by using a fluid of higher dispersive power than the glass lens CD, and making the interior curvature of the side CD, which touches the fluid, of that degree of convexity which will convert the fluid into a concave lens capable of correcting the colour of CD. The lens CD may be made most advantageously of fluor spar, which, from its low dispersive power, might form an achromatic combination with water.

Although, in so far as we know, metallic specula have never been regularly fitted up as a reflecting solar microscope for use, yet every person familiar with, and in the habit of using, specula and lenses, must have made the experiment of forming magnified images both in solar and artificial light, with small concave specula. The perfection of these images cannot be doubted; and it has often appeared to us surprising that the optician did not avail himself of such a combination for a solar microscope. Neither the Newtonian nor the Amician form of the instrument offer facilities for this purpose. Sir David Brewster has therefore proposed to employ his form of the reflecting microscope for a solar and oxyhydrogen instrument. Its facilities for this purpose are very great, and there can be little doubt that it will be practically successful, and will be as superior to other solar microscopes as the best reflecting compound microscope is to other compound microscopes. Dr Goring made an experiment with the Amician microscope; but he obviously considers it as not likely to succeed, remarking, that "after all that could be done, a refractor would be sure to beat it hollow; therefore I shall take my leave of the subject, as I cannot conscientiously recommend such an instrument."³ It is no wonder that this experiment failed, because Dr Goring seems to have used *the whole of the Amician microscope*, eye-glasses and all, as the magnifier in the solar microscope, and therefore it could not be considered as a *reflecting* solar microscope, being in fact as much a *refracting* one. The construction to which we have above referred is shown

Fig. 35.



¹ Treatise on New Philosophical Instruments, p. 410.

² See Treatise on New Philosophical Instruments, p. 401, for an account of the advantages of examining objects immersed in fluids.

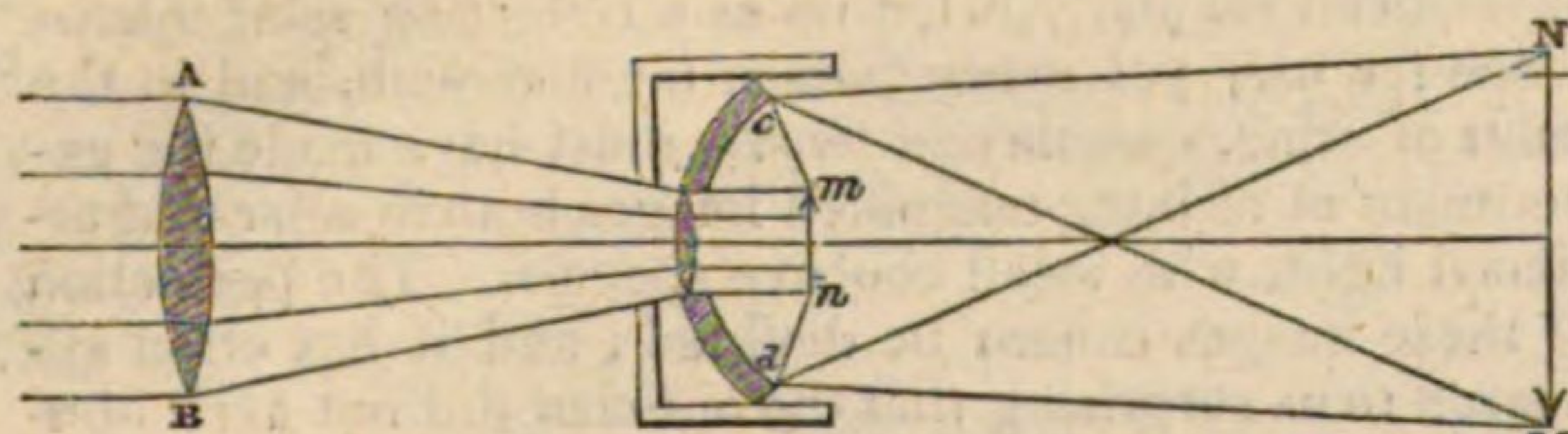
³ Dr Goring states, that a friend of his had constructed a solar microscope with metals on the Amician principle, and without a body or eye-glass, which exhibited a variety of test objects in a highly satisfactory manner.

Solar and Oxyhydro-gen Microscopes. in the annexed figure, where AB is the illuminating lens, throwing the condensed rays of the sun upon a transparent object *mn*. The rays from this object falling upon the small speculum *e*, are reflected to the deep concave speculum *cd*, so placed, that the image is formed at MN on a screen at some distance behind it, distinct vision being obtained either by moving the object or the speculum.

For opaque objects this form of the instrument is peculiarly adapted. The parallel rays of the sun falling upon the deep speculum *hh*, are condensed by it and thrown on the inner face of the object *mn*, of which a magnified image is formed, as before, at MN. A greater condensation of light may be obtained by using the lens AB, so that the speculum *hh* shall receive its convergent beam before the rays reach their focus and complete their convergency.

In this construction we have the disadvantage of two reflections, belonging also to the Amician form; but this may be considered as compensated by the image being without the tube, and more under our command. Though this is true in the compound microscope, yet the advantage of having the object outside the tube is of less consequence in a solar microscope. To avoid therefore two reflections, and two mirrors with their relative adjustments, Sir David Brewster has proposed to construct the reflect-

Fig. 36.



ing solar microscope in the manner shown in the annexed figure, where CD is the perforated concave speculum, *mn* the object in one of its foci, and MN the magnified image in its other focus. The object *mn*, placed on a slider passing through an opening in front of the speculum, is illuminated as an opaque object by the lens AB, whose refracted rays are farther condensed by a lens placed in the aperture of the speculum. This form of the solar microscope is therefore singularly adapted for opaque objects; and as the whole of the effect of the instrument is produced by a single reflection from a single surface, it is the simplest optical instrument in existence. In order to throw light upon *mn* as a transparent object, the rays must pass through it in an opposite direction from the side MN, and this may be done by the very same method given by Mr Potter, and represented in fig. 29.

The simplicity and practical value of this instrument will be immediately recognised by comparing it with the complex opaque box, which in all solar microscopes is a necessary appendage for opaque objects. See Plate CCCLXI. fig. 28 and 29.

Dr Goring's Solar Camera Microscope.

Dr Goring, whose indefatigable genius has improved almost all our popular instruments, has described in the *Micrographia* a very complete solar microscope, which has

the property of exhibiting the image on a horizontal curved surface, placed in a darkened camera, at which two or more persons can look at the same time. It is in reality a new instrument, but can also be used like the common solar microscope in a darkened room.¹

This instrument, with all its parts, is shown in Plate CCCLXI. figs. 30, 31, 32, and 33; fig. 30 being a geometrical elevation of the instrument *one-tenth* of the real size, the various parts being represented as if formed of transparent matter. A strong framework A of wood rests upon four legs, having a large hole in it, into which the instrument is fixed with two screws F, F. The frame is large enough to protect the observer from the solar rays. A long plane mirror B is fixed to an arm C, which moves round a pin fixed to the side of the mirror frame, and also round a joint attached to a strong round wire E, which slides backwards and forwards in the tube D, having a spring within, and a pinching nut to fix it in its place. The inclination of the mirror is varied by pulling out or pushing in the mirror, which has also another motion produced by the action of the milled head G on a rack and pinion. A common illuminating lens, five inches in diameter and one foot in focal length, is placed at H. Dr Goring recommends an achromatic lens² (which would be a very expensive appendage), though he says that he has never used one. The main body of the microscope is conical, having a bayonet catch at L to receive the rest of the instrument, viz. the tube carrying the stage and rackwork. This tube II moves within the conical one by means of the milled head M and rack and pinion N. The end of this tube is closed, and an ordinary slider-holder O is fixed to it. On the inner side of the stage, near N, is fixed a condensing lens, about one and a half inch in diameter and two inches in focal length, which, by means of a sliding wire passed through a hole in the stage, can be moved from one side of the tube to the other, and also made to approach to or recede from the stage. A second tube PPP, slit open at the sides, is screwed into the tube in which the stage moves; and into this tube the optical part *q* is made to slide, the object-glass being placed at K. Dr Goring here remarks, that "the focus may of course be roughly adjusted, by sliding the body backwards and forwards in its containing tube, before it is attached to the camera, fig. 31; but when this has been done, it must of course remain immoveable. I look upon it," he continues, "as a *principle* in the solar microscope, that the magnifier or object-glass should not be moved, but always remain at a fixed distance from the illuminator." Perhaps we do not distinctly understand the import of this passage; but we apprehend that the magnifier or object-glass may be, nay, must be moved in any way that is necessary to produce distinct vision upon the screen, whatever be its distance; and that the essential condition is, that the distance of the illuminator and the object shall be invariable, the object being, if possible, accurately situated in the focus, unless where a slight deviation is necessary to prevent its destruction by the concentrated heat of the solar rays.

The end of the tube Q is now pushed into another piece of tube at R, fig. 31, which communicates with a conical tube of brass, "having a rectangular prism, with its reflecting side silvered,³ or a plane metal adjusted at its head S,

¹ Dr Goring calls this instrument a *Solar Engiscope*, while he gives the name of *Solar Microscope* to the same instrument when used in a dark room in the common way. The introduction of the image into a camera becomes thus the reason for changing a *microscope* into an *engiscope*. The word *engiscope*, however appropriate it may be as a companion to the word *telescope*, is quite inapplicable to any kind of solar microscope.

² See Edinburgh Journal of Science, No. xi. new series, p. 85, and our chapter on the Illumination of Microscopic Objects.

³ Dr Goring is surely mistaken in saying that the side of the prism should be *silvered*; for as *total reflection* commences at $41^{\circ} 49'$ for glass, and takes place at all greater angles of incidence, the light incident at 45° will be totally reflected. But even if the least oblique part of the conical beam should penetrate the reflecting surface (which it cannot do), part of the picture would have the

Solar and so as to throw down the image to the bottom of the box or camera, where it is to be received on paper (at T), or on a surface of plaster of Paris duly curved to suit its shape." The camera WWXX is constructed with windows V, V, to permit two persons to view the picture on the table T. Two pieces of wood WW carved out to fill the slope of the upper part of the face, are placed as in the figure (one of them is shown separately in a plan at fig. 33). Dr Goring adds, that "he has found it necessary to exclude the breath from entering the camera, as it dims the eye-glass of the engiscope, and thus spoils the image;" but he does not mention whether this is the object of the pieces of carved wood, or whether they are used to keep extraneous light from the eye,¹ which, in so far as the figure indicates, does not appear to be the case.

The sides U, U of the camera may be removed at pleasure, to allow the observer to draw the picture on the table, the light being excluded by some black drapery, while the hand passes through a suitable opening in it. Dr Goring recommends that the whole of the exterior (interior?) of the conical brass tube and camera should be well blacked, or lined with black silk velvet.²

In applying this instrument to opaque objects, the opaque box, shown in fig. 32, is applied to the conical tube in fig. 26 by means of the bayonet catch at L. A plane mirror R, adjusted by the screw S, throws the light of the illuminator to the object O placed in the conjugate focus of the eye-glass K, by means of the milled nut M and screw T, which causes the stage and the object to approach to or recede from the lens K.³ The stage is formed by a piece of cork covered with black velvet. PP is the tube into which the body *q* of the microscope is inserted, as in fig. 26.

This instrument may be converted into a common solar microscope by unscrewing and removing the tube PP, and placing a simple object-glass in an appropriate mounting at M. The whole apparatus is then removed from the frame A, and screwed to a window shutter in the usual way.

On the Oxyhydrogen Microscope.

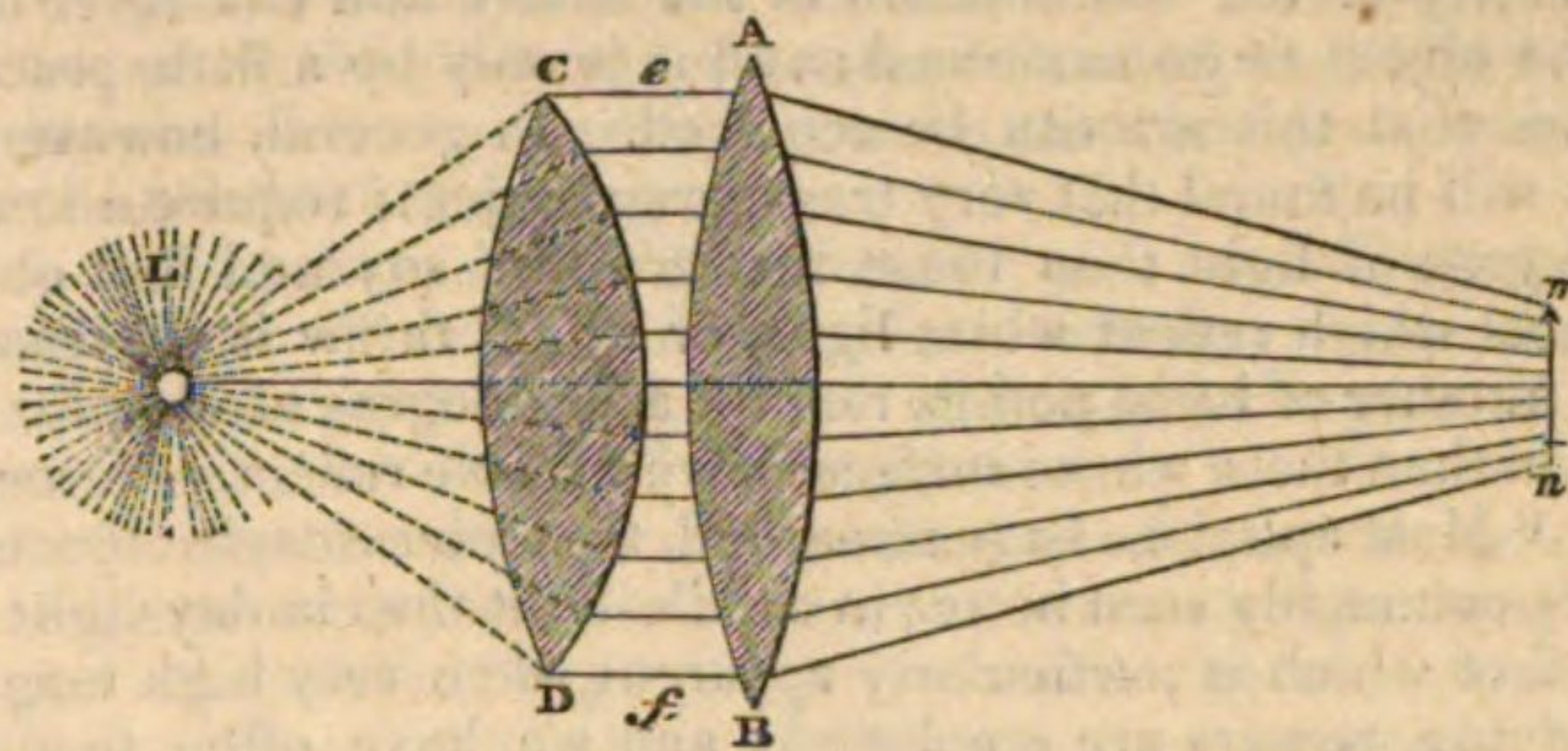
Oxyhydro- The great popularity of the public exhibition made with this instrument has turned the attention of opticians and amateurs to its improvement. Mr Pritchard has written a long and interesting chapter of nearly fifty pages on the subject of solar and oxyhydrogen gas microscopes, in the *Micrographia* already referred to, and has given a most popular and minute account of all the details of the instrument. These details, to which we must refer our readers, do not belong to an article like the present; and we shall content ourselves with explaining what an oxyhydrogen microscope is, and how the optical apparatus of a solar microscope may be readily converted into that of an oxyhydrogen one, and *vice versa*.

An oxyhydrogen gas microscope differs from a solar one chiefly in this, that a brilliant light obtained by igniting a ball of lime the size of a pea (hence called the *pea* or *lime* light, or more appropriately the *Drummond* light, from its inventor Mr Drummond) with oxyhydrogen gas, is substituted in place of the solar rays. This enables us to enjoy the amusement of the solar microscope apparatus in all weathers and at all hours of the day.

As the lime-ball light, however, is at our elbow, it sends forth diverging rays; whereas the rays of the sun are parallel. A very beautiful principle, already referred to in our article MICROMETER, enables us to give the simplest direction for this purpose. Let AB be the illuminating lens of the common solar microscope, throwing the parallel rays *ef* of the sun upon the object *mn*, and let the whole

Illumination of Microscopic Objects.

Fig. 37.



instrument be in perfect adjustment; then, without moving or changing any part of it, we may convert it into an oxyhydrogen microscope, where the light diverges from the lime ball L, simply by placing in front of AB another lens CD, whose focal length is equal to the distance of the lime-ball light L from the lens AB. The oxyhydrogen microscope will then have its objects at *mn* illuminated in precisely the same way as they were by the sun's rays. The two lenses CD, AB, should be in contact, the space being left to show the parallel rays *ef*. Now, as L is the focus of the lens CD, the converging rays *ef* will be parallel, and consequently will be refracted by AB, exactly as if they had been the rays of the sun.

If the instrument had been made originally as an oxyhydrogen microscope, with a large and deep lens at AB, which would be required to refract rays diverging from L to *mn*, then we might convert the instrument into a solar microscope by simply placing a *concave* lens in front of AB, whose focal distance is equal to the distance of L from AB. This concave lens will give such a divergency to the parallel rays of the sun that they will have their focus at *mn*.

Our readers will find the most ample details respecting the gas apparatus, and the method of managing and using the instrument, in Mr Pritchard's Essay in the *Micrographia* already cited.

CHAP. V.—ON THE ILLUMINATION OF MICROSCOPIC OBJECTS.

The methods of illuminating microscopic objects that have been long in use have been described in the preceding chapters. They consist in throwing light upon the object, either by means of a mirror or a lens, or both combined; but the nature of the light employed, the magnitude of the pencil, its condition with regard to parallelism, divergency or convergency, and the diameter of the pencil employed, or the direction in which it falls upon the object, have never been discussed as matters of science, and upon which the performance of the finest instrument essentially depends.

On the illumination of microscopic objects.

light of silvered reflection, and the other part the *double* light of total reflection, which would never answer. We would prefer a plane metallic speculum to the prism, even if sufficiently homogeneous not to affect the accuracy of the picture.

¹ In using this, and all other optical instruments where perfect vision is either agreeable or essential, we would recommend the use of the Greenland snow spectacles, cut to suit the individual from a plaster of Paris cast of the eyes, nose, and brow.

² Mr Potter found black velvet to be superior to any other blacking for the interior of his reflecting microscope. Edin. Journ. of Science, No. xi. p. 62, new series.

³ The illumination is here far too oblique. The mirror should be nearer P, and the screw MT should be made to move the object-glass K, in order that the focus of the illuminator may always fall on the object O.

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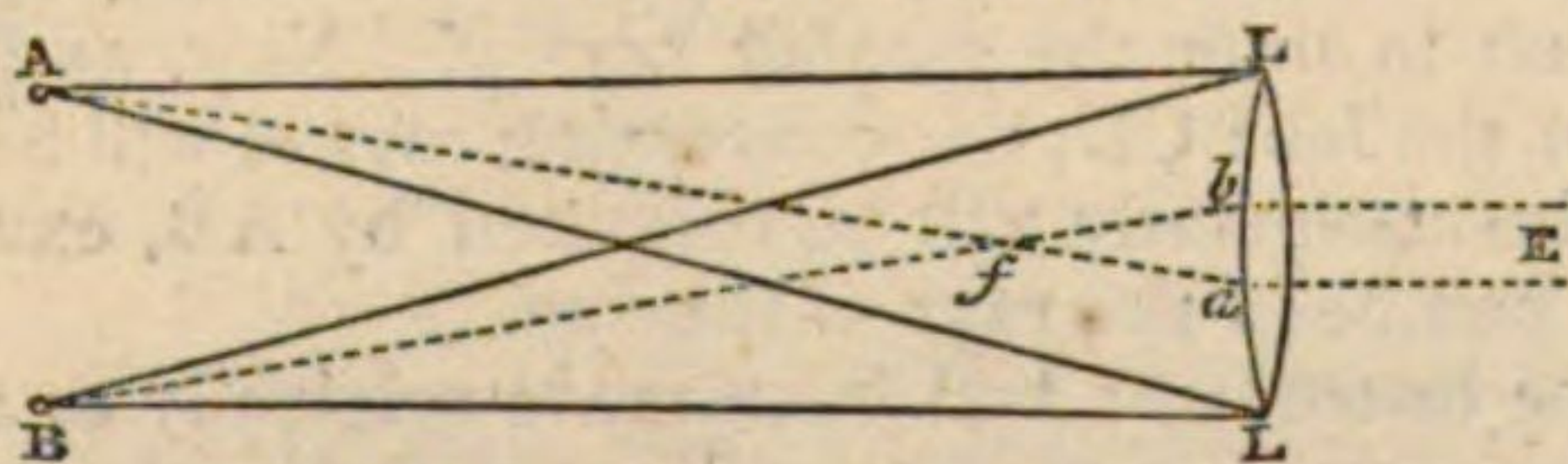
In so far as we know, the most important of these topics was pressed upon the notice of the scientific reader by Sir David Brewster, in the year 1820; and in order that the progress of improvement in this essential branch of the art of making discoveries with the microscope may be understood, we shall quote his observations on the subject.

"The art of illuminating microscopic objects is not of less importance than that of preparing them for observation. No general rules can be given for adjusting the intensity of the illumination to the nature and character of the object to be examined; and it is only by a little practice that this art can be acquired. In general, however, it will be found that very transparent objects require a less degree of light than those that are less so; and that objects which reflect white light, or which throw it off from a number of lucid points, require a less degree of illumination than those whose surfaces have a feeble reflective force.

"Most opticians have remarked, that microscopic objects are commonly seen better in candle-light than in day-light; a fact which is particularly apparent when very high magnifying powers are employed; and we have often found that very minute objects, which could scarcely be seen at all in day-light, appeared with tolerable distinctness in candle-light. So far as we know, the cause of this has not been investigated; and as it leads to general views respecting the illumination of microscopic objects, we shall consider it with some attention.

"Let LL, fig. 38, be a single microscope placed before

Fig. 38.



the eye at E, and let f be a microscopic object placed in its anterior focus, and illuminated by two candles at A and B. As the rays Afa and Bfb cross at f , the focus of parallel rays, and as the two shadows of the microscopic object will be formed at a and b , as it were, by rays diverging from f , the images of these two shadows formed upon the retina will coincide and make only one image, so that the object f will appear perfectly distinct. If the object, however, is placed either within or without the focus f , its shadows being formed, as it were, by rays diverging from a point either within or without the principal focus f , will not coincide on the retina, but appear to form two images, either overlapping each other, or completely separated. If, instead of two candles, A, B, we have 4, 5, or 6, we shall have 4, 5, or 6 overlapping or separated images. Now, as it is impossible to place the different parts of a microscopic object exactly in the focus f , and as every lens has different foci for the differently coloured rays, and even for homogeneous light, in consequence of its spherical aberration, it necessarily follows, that when microscopic objects are illuminated by light proceeding from several points, the image upon the retina must consist of a number of images not accurately coincident; and hence it becomes of the greatest importance that the object be *illuminated only from one point*, and not from a large surface of light, such as the sky, which is equivalent to an infinite number of radiant points.

"The following rules may therefore be laid down respecting the illumination of microscopic objects, and the method of viewing them.

"1. The eye should be protected from all extraneous light, and should not receive any of the light which proceeds from the illuminating centre, excepting that portion of it which is transmitted through or reflected from the object.

"2. Delicate microscopical observations should not be made when the fluid which lubricates the cornea of the observer's eye happens to be in a viscid state, which is frequently the case. See Brande's *Journal*, vol. ii. p. 127.

"3. The figure of the cornea will be least injured by the lubricating fluid, either by collecting over any part of the cornea, or moving over it, when the observer is lying on his back, or standing vertically. When he is looking downwards, as into the compound vertical microscope, the fluid has a tendency to flow towards the pupil, and injure the distinctness of the vision.

"4. If the microscopic object is longitudinal, like a fine hair, or consists of longitudinal stripes, the direction of the lines or stripes should be towards the observer's body, in order that their form may be least injured by the descent of the lubricating fluid over the cornea.

"5. The field of view should be contracted, so as to exclude every part of the object, excepting that which is under immediate examination.

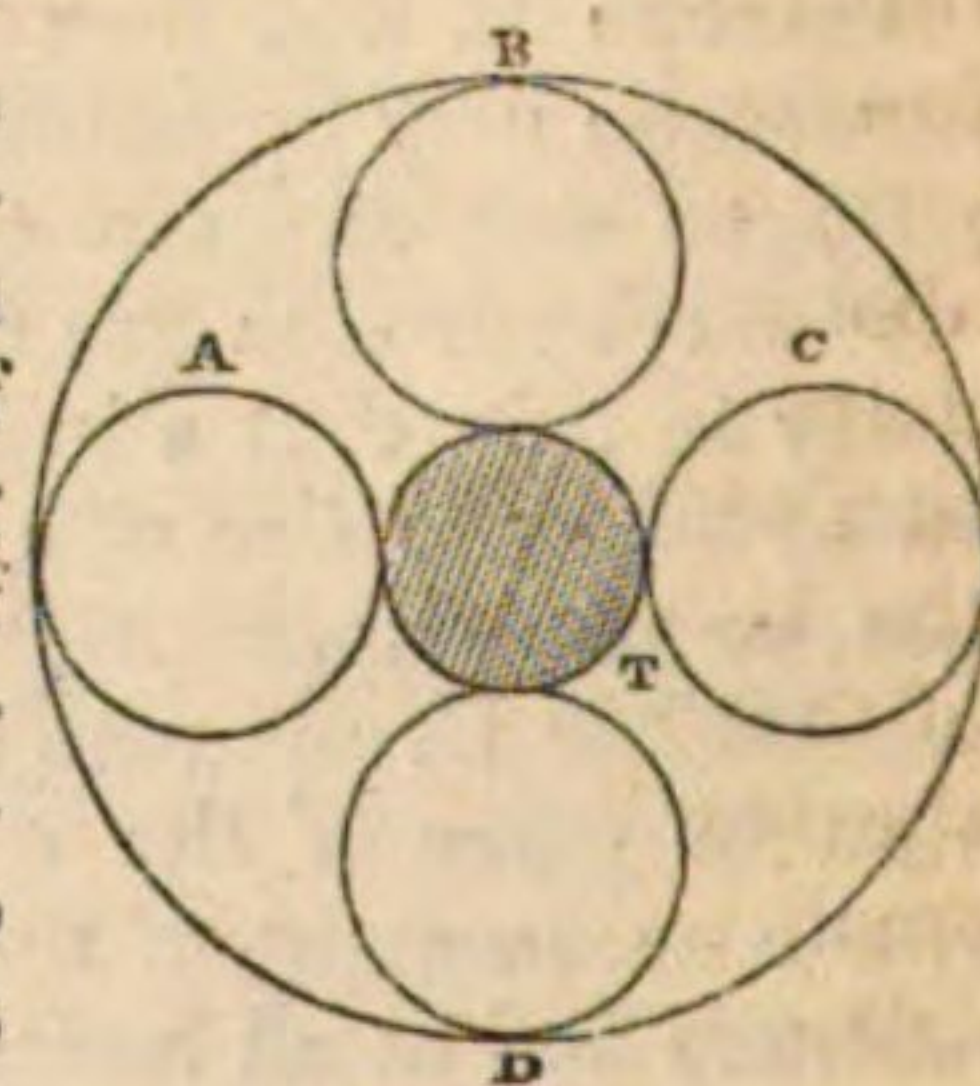
"6. The light which is employed for the purpose of illuminating the object, should have as small a diameter as possible. In the day time it should be a single hole in the window-shutter of a darkened room, and at night it should be an aperture placed before an argand lamp.

"7. In all cases, and particularly when very high powers are requisite, the natural diameter of the light employed should be diminished, and its intensity increased by optical contrivances.

"8. When a strong light can be obtained, and indeed in almost every case, homogeneous light should be thrown upon the object. This may be done either by decomposing the light with a prism, or by transmitting it through a coloured glass, which has the property of admitting only homogeneous rays."

In the same article Sir David Brewster has described "a new method of illuminating objects in the solar and the lucernal microscopes." "The great defects," says he, "which still attach to the solar and lucernal microscopes, arise from the imperfect method of illuminating the objects. The method suggested by Æpinus, and employed almost universally by opticians, of reflecting the light concentrated by a lens upon the objects, by means of a plane mirror, is good enough so far as it goes; but in consequence of the light arriving from one direction only, the surface of the illuminated object is covered with deep shadows, and the intensity of illumination is by no means sufficient when the power of the instrument is considerable. We propose, therefore, that in the solar microscope the sun's light should be reflected by a very large mirror through four apertures, A, B, C, D (surrounding the tube T), each of which is furnished with an illuminating lens. The four cones, if condensed, are then received, before they reach their focus, each by an inclined mirror, which reflects them upon the object; the distance of the lens from the mirror, added to the distance of the mirror from the object, being always less than the focal length of the illuminating lens. In the lucernal microscope it would be desirable to place an argand lamp opposite each of the apertures A, B, C, D. By these means the light would fall upon the surface of the object in four different directions; a high degree of illumination would be obtained for very dark objects; and by shutting up one or more of the four lenses, or parts of them, we shall be enabled to find the particular direction of the light which is best suited for developing the structure which it is the object of the observer to discover." Although the focus of the illuminating rays

Fig 39.



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should always fall upon the object, for the reasons already assigned, yet in the preceding method, applied to the solar microscope, a deviation from this rule becomes necessary, for two reasons: 1st, Because, if the focus of the illuminating lens fall exactly upon the object, it might burn it, or destroy it by corrugation; and, 2dly, In the ordinary illuminating lenses, the diameter of the focal spot, or image of the sun, is not sufficient to cover the whole object, or to give a sufficient luminous field around it. For these reasons it is recommended in the preceding extract to place the object a little way within the focus of the illuminator, that is, between the illuminator and its focus. But if the object is such that it cannot be injured by the solar heat, or if the illuminator is sufficiently large to give a focal spot capable of filling the field of the microscope, then the object should be placed in the solar focus of the illuminator.

Dr Wollaston's
method of
illumina-
tion.

After a lapse of nearly ten years, the subject of microscopic illumination was discussed by Dr Wollaston, in his paper on the microscopic doublet, published in the Phil. Trans. for 1829. This eminent philosopher, whose ingenuity never failed in executing in the best manner whatever he attempted, was then on his death-bed; and this, among other papers, was published without that complete revision which its author would otherwise have given it.

"The state of my health," says Dr Wollaston, "induces me to commit to writing rather more hastily than I have been accustomed to do, some observations on microscopes; and I trust that, in laying them before the Royal Society, they will meet with that indulgence which has been extended to all my former communications."

"In the illumination of microscopic objects, whatever light is collected and brought to the eye beyond that which is fully commanded by the object-glasses, tends rather to impede than to assist distinct vision."

"My endeavour has been to collect as much of the admitted light as can be done by simple means, to a focus in the same plane as the object to be examined. For this purpose I have used with success a plane mirror to direct the light, and a plano-convex lens to collect it; the plane side of the lens being towards the object to be illuminated."

These two principles of illumination, the first of which is the same as the first and fifth of the rules already given, though not so fully developed, and the second founded upon a mistaken principle, have been carried into effect by Dr Wollaston in the following manner:

"T, U, B, E represents a tube about six inches long, and of such a diameter as to preclude any reflection of false light from its sides; and the better to insure this, the inside of the tube should be blackened. At the top of the tube, or within it at a small distance from the top, is placed either a plano-convex lens ET, or one properly curved, so as to have the least aberration, about $\frac{3}{4}$ ths of an inch focus, having its plane side next the object to be viewed; and at the bottom is a circular perforation A,

of about $\frac{3}{10}$ ths of an inch diameter, for limiting the light reflected from the plane mirror R, and which is to be brought to a focus at a, giving a neat image of the perforation A, at the distance of about $\frac{8}{10}$ ths of an inch from the lens ET, and in the same plane as the object which is to be examined. The length of the tube, and the distance of the convex lens from the perforation, may be somewhat varied. The length here given, six inches, being that which it was thought would be most convenient for the height of the eye above the table, the diameter of the image of the perforation A must not, excepting with lower powers than are here meant to be considered, exceed one twentieth of an inch.

"The intensity of illumination will depend upon the diameter of the illuminating lens and the proportion of the image to the perforation, and may be regulated according to the wish of the observer. * * *

"The lens ET, or the perforation A, should have an adjustment by which the distance between them may be varied, and the image of the perforation be thus brought up to the same plane as the object to be examined. * *

"For the perfect performance of this microscope, it is necessary that the axis of the lenses, and the centre of the perforation A, should be on the same right line. This may be known by the image of the perforation being illuminated throughout its whole extent, and having its whole circumference equally well defined. For illumination at night, a common bull's-eye lanthorn may be used with great advantage. * * *

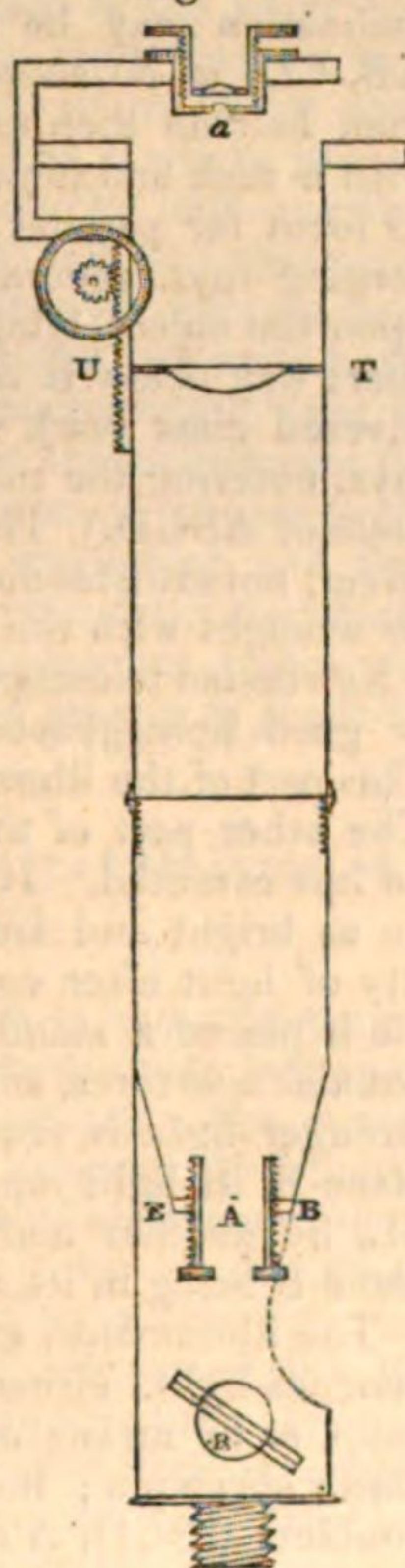
"Supposing the plano-convex lens to be placed at its proper distance from the stage, the image of the perforation may be readily brought into the same plane with the object, by fixing temporarily a small wire across the perforation with a bit of wax, viewing any object placed upon a piece of glass upon the stage of the microscope, and varying the distance of the perforation from the lens by screwing its tube until the image of the wire is seen distinctly at the same time with the object upon the piece of glass."

In the preceding passages we have extracted every one of Dr Wollaston's observations in reference to his method of illuminating microscopic objects, so that the reader will be enabled thoroughly to understand it.

This method of illumination was highly commended by optical writers. Dr Goring¹ considered it as most effective, and enumerates it among the inventions which founded a new era in the history of the microscope; and he elsewhere states, that "there is no modification of daylight illumination superior to that invented by Dr Wollaston."²

The marked difference between the methods of illumination proposed by Dr Wollaston and Sir David Brewster, induced the latter to publish, in 1831, a paper "On the Principle of Illumination of Microscopic Objects."³ In this paper the mistake committed by Dr Wollaston is clearly pointed out. The rays which Dr Wollaston throws upon the object, in place of being rays actually converged to a focus, as they ought to be, are rays which diverge from a focus situated between the object and the lens. He makes the focal point of the circular margin of the perforation fall upon the object, without considering that the rays which pass through that perforation do not diverge from it, and therefore cannot be collected in the conjugate focus corresponding to the perforation. In Dr Wollaston's diagram (Phil. Trans. 1829, plate ii. fig. 1), the rays which are incident on the mirror R are actually drawn as parallel rays; and it is quite clear that he meant them to be parallel rays issuing from the bull's-eye lanthorn which he re-

Fig. 40.



¹ Microscopic Illustrations, Exord. p. 1, Lond. 1830.

² Microscopic Cabinet, p. 181, Lond. 1832.

³ Edinburgh Journal of Science, new series, No. XI. p. 83.

Illumina-
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Objects.

commends. But if we suppose that a common flame is used, the error is just of the same nature. It is a distinct image of the *flame* that should be thrown upon the object; and hence the perforation A should be placed close to the flame,—the source of light and the illuminated object forming the conjugate foci of the lens. After explaining this principle, Sir D. Brewster adds in the same paper:—"I have no hesitation in saying, that the apparatus for illumination requires to be as perfect as the apparatus for vision; and on this account I would recommend that the illuminating lens should be perfectly free of chromatic and spherical aberration, and that the greatest care be taken to exclude all extraneous light, both from the object and from the eye of the observer."

At the meeting of the British Association at York in 1831, the preceding methods were communicated to Mr Potter, who was then engaged in inquiries with the reflecting microscope, and who had used only the common method of illuminating his objects. The effect which he obtained by it is thus described.¹ "I am indebted to Dr Brewster for information on the necessity of having the focus of the illuminating lens for transparent objects to fall exactly upon the object, when great nicety of vision is required. Having adjusted my microscope carefully on this point (see our figure, p. 41, where the object is seen in the focus of the illuminating rays), I saw quite easily what are called the diagonal lines on the scale from the wing of the white-cabbage butterfly, which has been proposed as a difficult test object by Dr Goring; and it is such a one as those who have only seen the stronger longitudinal striæ on scales from the wings of moths and butterflies have little idea of." By the same means Mr Potter's instrument "showed him easily not only the striæ on the scales of the wing of the small house-moth, but also the diagonal lines." Mr Potter afterwards applied his microscope, and the new method of illumination, to "a much more difficult object than those just referred to." This object is the broad bluish band first noticed in the web of the spider, the *Clubiona atrox*.² "There can be no doubt," says Mr Potter, "that this blue band consists of lines produced by the spider, and woven into the delicate tissue. To demonstrate these fibres, however, is a work for an expert microscopist, provided with a first-rate instrument. So critical a defining power is required, at the same time with a large quantity of light, that I doubt much whether any compound refracting microscope, even the best achromatic, will ever show the construction of this web on a transparent object. When viewed in this manner through good common compound microscopes, the blue band can scarcely be perceived at all with a moderately high power. It is better seen as an opaque object by the light of the sun, and it was on this method that I discovered it, when highly illuminated and highly magnified, to be covered very regularly and closely with white spots. This was sufficient information that it was of an uniform texture; but as there is always in such a light a strong display of irradiations and prismatic colours, it was impossible to trace the fibres. I had discovered something of the texture with small globules of glass, used after the manner prescribed by Leewenhoeck; but with very high powers the distinct field of view is so small, that I dared hardly to pronounce decidedly upon the general structure; and it was only after adjusting the illuminating lens of my microscope very carefully, that I saw with it the complete structure of a regularly woven net."³

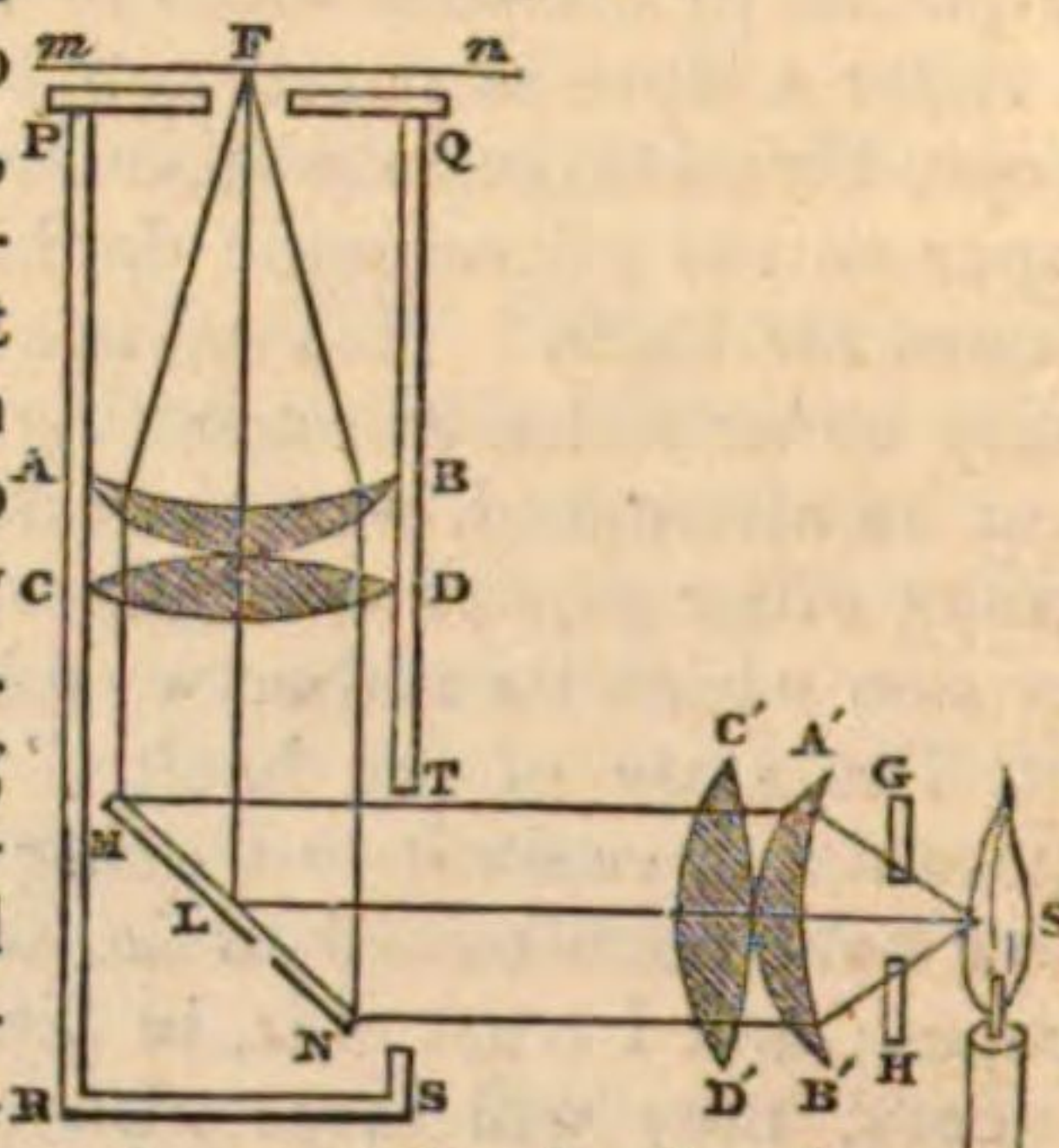
After this strong testimony to the practical utility of Sir David Brewster's method of illumination, and the unquestionable optical principles on which it is founded, we were surprised to observe that Dr Goring and Mr Pritchard should, in the *Microscopic Cabinet*, published in 1832, still recommend and use a method so decidedly erroneous in theory, and founded on no optical principles whatever. Dr Goring has even contrived what he calls an improved illuminator, which is just Dr Wollaston's, with a stop in the focus of the lens.

As the progress of discovery with the microscope must depend upon the scientific illumination of the objects under examination, we shall proceed to describe, in detail, the method of illumination used by Sir David Brewster.

Let mn be the plane surface on which the object rests accurately perpendicular to the axis of the lens, lenses, or mirrors, which constitute the microscope. Let PQRST be a tube from one and a half to two inches long, and wholly lined with black velvet. This tube has an opening at ST, and must be so attached by an universal joint, or any analogous contrivance, to the slider-holder, that the axis FL of the tube can be inclined at any angle to the surface mn from 90° , its general position, to 60° or less, as circumstances may require. It should also have a circular motion about its axis, in order that the inclination may be made in any azimuth. A doublet AB, CD, of no aberration, and having a focal length of from half an inch to an inch, is then placed in the tube, with a rack and pinion, or any other adjustment, to bring its focus for parallel rays F, or its conjugate focus for diverging rays, accurately to a point in the plane mn , and upon the object lying in that plane, for examination. A short way below it is placed a metallic speculum (not a silvered glass one), which receives parallel or diverging rays, entering the tube at ST, and reflects them upon the doublet ABCD. This speculum should be of pure virgin silver, notwithstanding its liability to tarnish, and should be wrought with the same care as the plane speculum of a Newtonian telescope; or it might be a rectangular prism of good homogeneous glass, acting by total reflection. This part of the illuminator forms part of the microscope.³ The other part of the illuminator, which is detached, is no less essential. It consists of the flame S, which should be as bright and small as will give the necessary quantity of light after condensation. As close to it as possible is placed a stand for holding a screen, with different circular apertures, and a variable rectilineal aperture. If a stronger light is required than can be obtained from the plane S, its light must be condensed into a parallel beam SL, by another doublet of no aberration, A'B'C'D', the flame S being in its anterior focus.

The illuminator, as now described, is adapted to homogeneous light, either as obtained from a monochromatic lamp, or by means of coloured glasses, or from the prismatic spectrum; but if we employ common light, the doublets ABCD, A'B'C'D' must be achromatic. We have

Fig. 41.



¹ Edinburgh Journal of Science, new series, No. XI. p. 64.

² It is found in the crevices of old walls, and may be recognised by its irregular fleecy-looking web.

³ Mr Pritchard received from Mr Potter a specimen of this web; but though he detected the blue bands, yet, as the specimen was not a recent one, he was unable to perceive "the complete structure of a regularly woven net." (*List of 2000 Microscopic Objects* p. 6, 7.)

⁴ If the axis of the microscope is placed horizontally, or even with some obliquity, we may dispense with this speculum altogether, and direct the tube at once to the illuminating flame.

Illumina-
tion of Mi-
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Objects.

Illumina-
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Objects.

mentioned above a variable rectilinear aperture. This is a most essential accompaniment for giving perfection to the vision of lined objects. The aperture should be made to form every possible angle with a vertical line, and should be opened and shut by means of a screw, till as much light is introduced as is necessary to obtain a perfect view of the object. The image of the slit, which is close to the flame, must be thrown upon *mn*, so as to be parallel with the lines of the object. When the objects are circular, circular apertures are preferable to any other.

We have already stated that no light should reach the eye, either from the field of the microscope, or any other source. For this reason it would be desirable to have circular and rectilinear apertures of different sizes, to be placed immediately beneath *mn*, so as to allow no part of the field to be seen, excepting that which is occupied by the object or part of it under examination.

The above apparatus being provided, let us suppose that the observer is called to examine some structure very difficult to be resolved, such as the blue band of the *Clubiona atrox*, or the structure and nature of the lines on test objects. We omit at present the consideration of the preparation of the object and the eye of the observer, and also the nature of the light which he is to use, as these will be separately considered; and confine ourselves to the use of the illuminator. The object is first placed on a piece of thin colourless parallel glass, or film of topaz or sulphate of lime, near its middle, and the microscope is directed to it, so that it can be seen distinctly in the ordinary way. Put the illuminator in its place, and set the proper aperture close to the small plane. Adjust the doublet ABCD by its screw or pinion till a distinct image of the aperture GH is seen in the field; and, by means of the apertures below *mn*, any strong or unnecessary light may be still more completely excluded. If the structure is not rendered sufficiently distinct by this process, it will be proper to try the effects of oblique illumination, by inclining the axis FL of the illuminator to the plate *mn*, and observing carefully the effects which it produces in different azimuths. If all these means are insufficient, we must have recourse to new auxiliaries,—to monochromatic light if the microscope is not achromatic, or to monochromatic illumination if it is achromatic; and we must prepare both the eye and the object, the one for exhibiting and the other by viewing to the best advantage the structure which we are anxious to develop. These important topics we shall treat in their order, with as much brevity as possible.

CHAP. V.—ON THE MONOCHROMATIC ILLUMINATION OF MICROSCOPIC OBJECTS.

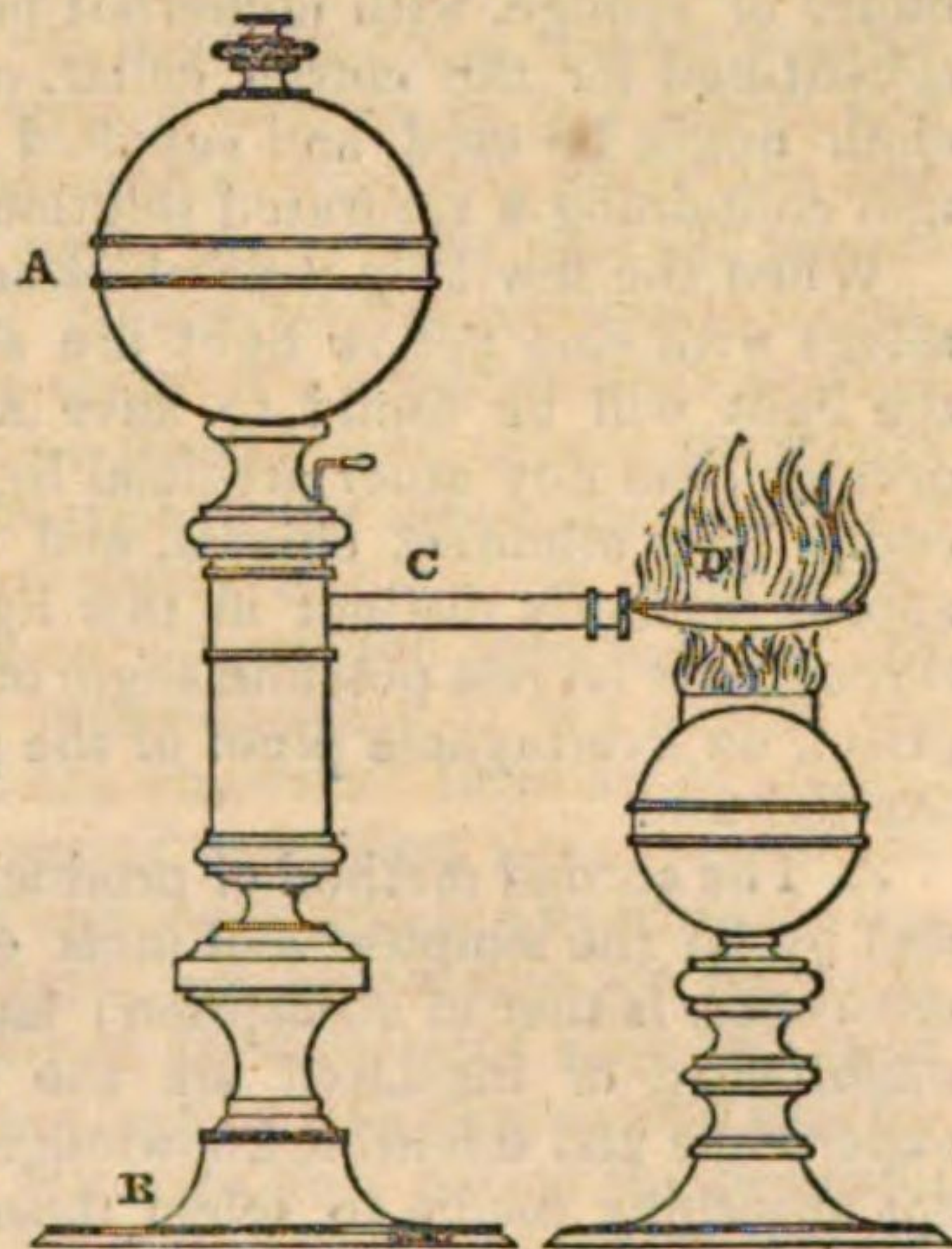
If a simple and easily applied system of monochromatic illumination, that is, of illuminating objects with homogeneous light, which a prism, and consequently a lens, is not capable of dispersing or refracting in different directions, could be contrived, we should never again hear of compound achromatic microscopes. We believe it will be admitted, that in Sir John Herschel's doublet of no aberration, the spherical aberration is more completely corrected than in any double or even triple achromatic object-glass. Hence it follows, that in homogeneous light such a doublet would be a better microscope than the compound lens. But in the best system of achromatic compensation that can be executed, the secondary spectrum still remains without a remedy; and hence the doublet of no aberration, in which

there can be no secondary colour in homogeneous light, must be a superior instrument to the compound achromatic lens. Now, in telescopes it is impossible, except in viewing the sun's disc,¹ to work with homogeneous light; but in microscopes, where the quantity of light is in our power, it is perfectly practicable to make that quantity so great that all the yellow or red rays which it contains may give sufficient light for microscopical observations. This insulation of homogeneous light may be effected in two ways; 1st, by a monochromatic lamp, as proposed and constructed by Sir David Brewster; 2dly, by the absorption of coloured media; and, 3dly, by the prism.

The monochromatic lamp is shown in the annexed figure, where AB is a lamp having its globe A filled with diluted alcohol, which descends gradually through the tube C, into a thin platina or metallic cup, in which it burns. A strong heat is kept up by a spirit lamp L enclosed in a dark lantern, and when the diluted alcohol is inflamed, it will burn with a fierce and powerful yellow flame. If the flame should not be perfectly yellow, or rather of a *nankeen* colour, owing to an excess of alcohol, a small proportion of salt thrown into the cup D will have the same effect as a farther dilution of the alcohol. Sometimes a little blue light will be found mixed with the yellow, but this may be easily absorbed by a piece of yellow glass placed on any part of the microscope through which the rays pass. Although this light is feeble compared with that of white flames, yet, by using larger lenses for condensing it, it is quite easy to obtain a pencil sufficiently powerful for all microscopical observations.²

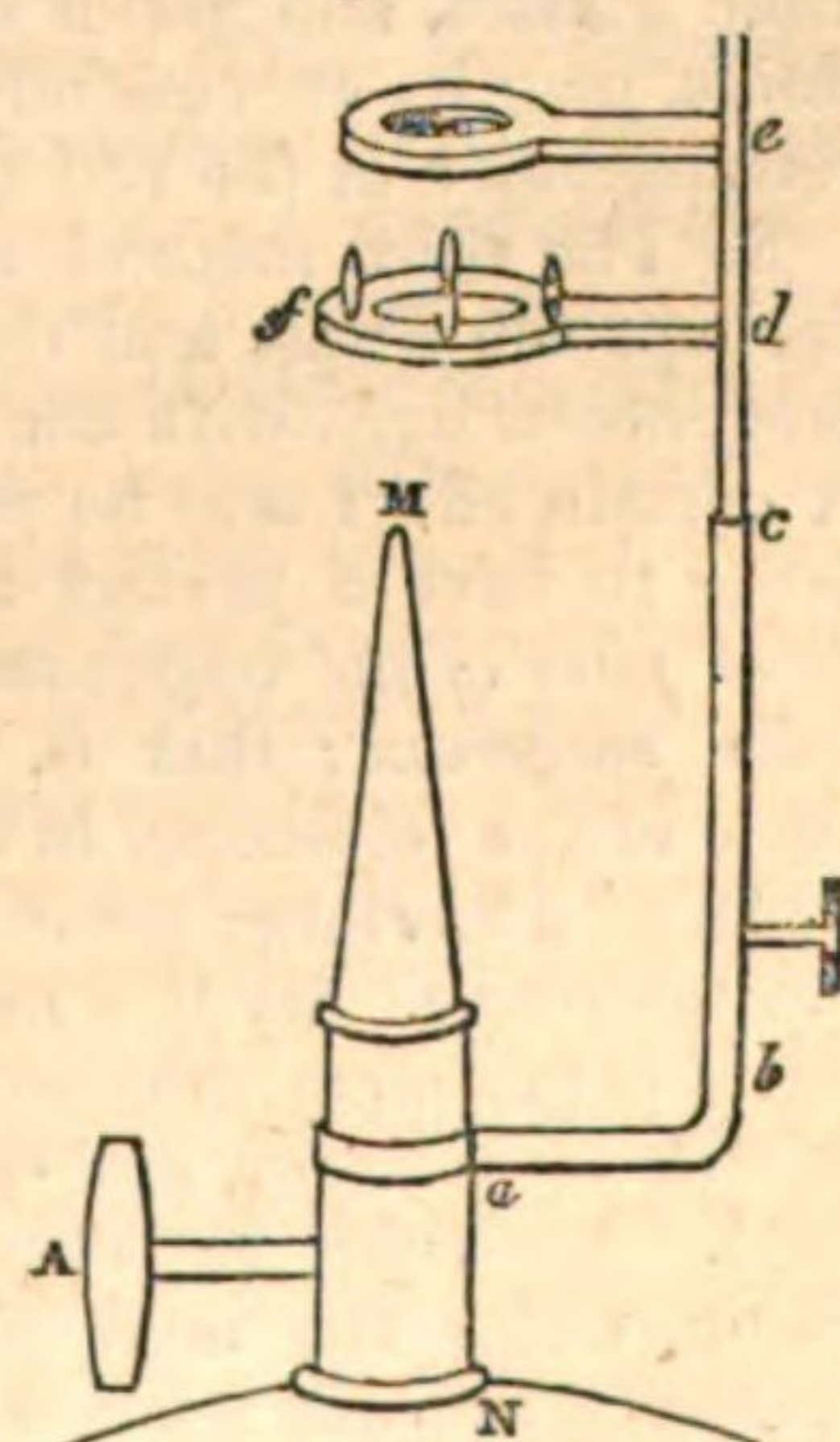
A stronger flame may be produced by using a gas Monochromatic lamp, or, what is still better, a portable gas one containing compressed gas. This gas, when rushing out in a full stream, explodes when burned with atmospheric air, emitting much heat, and a faint bluish and reddish light. As the force of the issuing gas is sufficient to blow out the flame, a contrivance for sustaining it becomes necessary. The method which we contrived for this purpose is shown in the annexed figure, where PQ is the main body of the lamp, MN the principal burner, and A the screw which opens the main cock. A small gas tube *abc*, communicating with the main burner, terminates above the burner, and has a short tube *de* moveable up and down within it, but so

Fig. 42.



Monochromatic lamp.

Fig. 43.



Monochromatic gas lamp.

¹ A solar telescope should never be an achromatic one, but should consist of a compound lens of no aberration, all the colours of the spectrum being corrected by the dark glass.

² Edinburgh Transactions, vol. ix. p. 435.

as to be gas light. This tube *de*, closed at *d*, communicates with the hollow ring *fg*, in which four apertures are perforated so as to throw their jets of gas to the apex of a cone whose base is *fg*. When the gas is made to issue from the burner *M*, it rushes also into the tube *abcdg*, and issues in four small flames at the apertures in the ring *fg*; and the height of these flames is regulated by the stop-cock at *b*. The explosive mixture of air and gas which rushes up through the ring is sustained in combustion by these small flames, through which it passes. A broad collar, made of coarse cotton-wick, and thoroughly soaked in a saturated solution of common salt, is fixed on a ring *h*; and when the bluish flame of the explosive mixture rises above *h*, it will be converted by the salted collar into a strong mass of homogeneous yellow light. A hollow cylinder of sponge, with numerous projecting tufts, may be substituted for the cotton collar, or a collar of asbestos cloth might be used, and supplied from a capillary fountain containing a saturated solution of salt.¹

When the few blue rays which sometimes mingle themselves with this yellow light are absorbed, every part of the light will be found to have a definite refrangibility greater than any other artificial light that can be produced. The minutest objects, and the smallest type, will appear perfectly distinct in this light when seen or read through the largest possible angle of the greatest dispersive prism, an irrefragable proof of the perfect homogeneity of the light.

Absorption.

2. The second method of producing homogeneous light, and by far the simplest and most easily applicable to microscopes, is that of absorption; and the best rays to leave unabsorbed or insulated are the red. It requires some experience and scientific knowledge of the action of different absorbing media to select those which will leave the *narrowest and brightest band* of the red space in the spectrum. We have now under our microscope (a grooved sphere of garnet executed by Mr Blackie²), two scales of a moth lying in sulphuric acid, and covering each other. With solar light the spaces between the lines glitter with all the hues of the rainbow; but when a thickish plate of red mica is combined with another plate of red glass, and placed beneath the object, all these colours instantly disappear, and a perfection of vision is obtained, which can be disturbed only by the very small portion of spherical aberration which must exist in the sphere, and which an increased depth of the groove would render almost insensible. Blue glasses, and green and yellow, as well as coloured fluids, may be successfully used in narrowing the range of refrangibility of the red space.

Prismatic refraction.

3. The third method, or that of prismatic refraction, is perhaps the surest and the best method of obtaining homogeneous light with the smallest extent of refrangibility. A certain effect may be produced by small prisms; but in order to have a perfect apparatus, the *microscope should form part of the apparatus for examining the lines of the solar spectrum*; that is, it should screw into the eyepiece of the telescope, in front of the object-glass of which is placed a fine large prism, for forming the spectrum within the telescope. By this method, which we have put to the test of experiment, microscopical observations can be carried on with an accuracy and satisfaction which nothing can exceed. We enjoy the luxury of perfectly monochromatic vision, which the most perfect achromatic compensation cannot give; and while we have the spherical aberration corrected, we have no secondary colours, and none of

the imperfections of vision which must arise in transmitting light through six or eight lenses of plate and flint glass.

Although we hope that the scientific reader will admit that the preceding views are demonstrably correct, yet Dr Goring has pronounced a most unfavourable opinion of the system of monochromatic illumination.³ We have already endeavoured to convert him from this heresy, and hoped that we had succeeded;⁴ but in the *Micrographia*, just published, he has devoted a whole chapter to the reproduction and support of his former views.⁵ We shall therefore again examine his objections in their order, as they obstruct the progress of improvement among those who justly admire Dr Goring's ingenuity and knowledge in every thing which relates to the microscope.

1. Dr Goring's first objection to monochromatic illumination is, that it is too weak, and must be about one seventh of the whole beam of light. This we are not disposed to dispute; but Dr Goring is too well acquainted with the resources of optical science, to forget that this monochromatic seventh of a beam of light may be made *seven* times more intense than the whole beam. The objection, however, does not apply to the solar spectrum, for one seventh of the sun's light is too intense for any eye to bear.

2. The second objection of our author is, that the colours of the spectrum, when separated by the prism, are actually separated into different colours when they are refracted in oblique pencils by a microscope. If this observation is correct, then we must denounce the prism that produced such a spectrum as utterly useless. Dr Goring, however, conceives his observation and his prism to be good, and endeavours to explain the result by referring to Sir David Brewster's analysis of the spectrum, in which it is shown that white light exists at every point of it; but this white light, which has been rendered visible by absorption, cannot be decomposed by refraction of any kind, as it consists of red, yellow, and blue rays, of the same refrangibility. Such white light is the light that is wanted for the microscope; and there can be little doubt that absorptive media will yet be discovered to effect its insulation in sufficient quantity for practical purposes.

3. Another objection to monochromatic light is, that it will not show the real colours of microscopic bodies. This is true; but the object of the microscope is not to find out colours, but structures. A common glass lens, with common light, will let the observer have all that he wants of the colours of objects; and when he has learned this, he will then gladly avail himself of coloured light for more important purposes. We can truly say, that though we have wrought with the microscope for thirty years, we do not at present recollect a single case where we required to know any thing of the precise colours of minute bodies. Notwithstanding this discussion, Dr Goring concludes his chapter with the following observation, in which we entirely concur. "A monochromatic light, therefore, being once obtained *in a sufficient state of intensity for practical purposes*, bids fair to conduct us to the highest perfection of which aplanatic object-glasses and magnifiers are susceptible." It may be proper to add, that the best system of compound achromatic object-glasses now in use would be freed of all their secondary colours, by using monochromatic light; and they may be also greatly improved by employing suitable coloured media to absorb what are called the outstanding rays in an achromatic combination.

¹ Edinburgh Journal of Science, new series, No. I. p. 103.

² This sphere, which we have already mentioned, is made of the purest garnet, and is executed in the most admirable manner; and though we cannot say that we see any defect in it, yet if the groove were still deeper, both its spherical and achromatic aberration would be diminished.

³ Edinburgh Journal of Science, new series, No. IX. p. 52.

⁴ *Ibid.* p. 143.

⁵ Page 73.

Prepara- CHAP. VI.—ON THE PREPARATION OF THE OBJECT AND
tion of the THE EYE FOR MICROSCOPICAL OBSERVATIONS.
Object and
the Eye.

Prepara-
tion of the
object.

In using lenses of short focus, either singly or in doublets and triplets, the object is so near the lens, and its thickness, even when very small, forms such a considerable part of its distance from the nearest refracting surface, that any bend or want of flatness in the object completely interferes with the distinct vision of its parts. When the object will bear pressure, the best way is to lay above it a thin transparent film, with perfectly parallel and polished surfaces, such as a splinter of New Holland topaz, a thin plate of sulphate of lime, or a film of mica. If these plates are a little less thick than the distance between the lens and the object, a little bees-wax should be interposed between the brass setting of the lens and the plate, so that the lens in the act of adjustment would press the wax against the plate, and the plate against the object, till distinct vision is obtained. The object should be placed upon a deeply curved concave surface.

The proper flattening of the object, when it is tender, may be effected by pressing a thick balsam above it, and allowing the lens to dip into the balsam. If the surface of the lens is flat, its magnifying power will suffer no diminution.

When grooved spheres are used, such as the garnet one above mentioned, the object requires to be very near its surface. It should therefore be placed in a concave lens of glass, of a little greater radius than the sphere, and pressed into the concave form by interposing a narrow strip of a thin film of mica, and, if necessary, pieces of wax or India-rubber, as before; the pieces filling up the space between the lens and the mica, so as not to interfere with the part of the object under examination.

If a diminution of the magnifying power can be permitted, a fluid may be placed between the concave object-plates and the grooved sphere, and the chromatic aberration greatly reduced. By the interposition of a fluid a grooved diamond sphere may be used; for though its focus for parallel rays falls within the sphere when the refractions are made from air and into air, yet when the first refraction is made from a suitable fluid, the focus will fall without the sphere.

When the object is put into the best possible condition for observation, and the illuminator applied in the best possible manner, the observer will have every advantage in his researches; but still the structure which he seeks to develop may escape his eager research. Under these circumstances, he must perform his part of the observation in the best possible manner.

Prepara- Unless particular arrangements are made by the ob-
tion of the server for his own comfort, there is no bodily fatigue to
eye. be compared with that of the use of the microscope. The eye, the mind, and the whole frame, are on the stretch. The observer must therefore first try if his own eye is in a right state for observation. The fluid which lubricates the cornea, which must be considered as a lens, and as part of the microscope, is sometimes in such a viscid state, that when the eyelids roll over the cornea by that beautiful provision of nature by which it is kept smooth and clean, the lubricating fluid, which is pushed into a ridge between the eyelids, does not quickly recover a convex surface. This state of the cornea is incompatible with delicate microscopic observations, and its existence may be ascertained by viewing the expanded image of a luminous point held close to the eye, and, after shutting the eyelids and again opening them slowly, observing if the luminous

disc recovers its uniform luminosity quickly or slowly. If the luminous line produced by the fluid accumulated between the eyelids continues to be visible, and the general surface mottled and spotted, the lubricating secretion should be excited by exposing the eye to the vapour of hartshorn, raised by pouring a few drops on the surface of boiling water. The secretion will now flow copiously, the cornea will be swept clean by the purer and less viscid fluid, and the vision of the observer greatly improved. But this moveable fluid surface of the cornea generates another imperfection of vision, which has already been referred to. This fluid, when undisturbed by the eyelids, descends by the influence of gravity in vertical lines, and the minute ridges thus formed obliterate and render indistinct all horizontal lines seen by the eye, but have a tendency rather to improve the vision of vertical lines. In proof of this, we may state the unquestionable fact, that if we take a striped pattern of any fabric, and bend part of it into a horizontal direction, while the rest remains vertical, or *vice versa*, the vertical part will always appear the most distinct. Hence, in viewing lined objects, when the position of the observer's head is either vertical or oblique, the lines of the lined object should be always placed parallel to the direction of the descending fluid. If the axis of the lenses is vertical, and the eye looks downwards, the lubricating fluid will collect irregularly at the apex of the cornea, and injure vision. If the axis of the lenses is horizontal, and the observer's head in its natural position, the fluid will descend in vertical lines; but if the observer lies on his back and looks into the microscope upwards, a position, we admit, not favourable for research, the fluid will flow equally in all directions from the apex to the margin of the cornea, and leave a clear centre well fitted for distinct vision. We may here notice the beautiful contrivance, not mentioned by natural theologians, that the effect of vertical descent of the lubricating fluid is counteracted by the eyelids opening horizontally, and consequently effacing the tendency of the fluid to form vertical currents. Had the eyelids opened vertically, the vertical ridges would have been increased, and vision greatly impaired.

When every thing has been done to fit the *cornea* (the only part of the eye over which we have any direct command) for accurate vision, the general state of the health, or any casual irregularity of diet, will be sometimes found to affect the state of the organ, and unfit it for nice observation. To remedy this defect of vision, we must refer the patient to the simplest prescriptions of his physician.

When these precautions have been taken, the observer must protect his eye from all extraneous light; and the most effectual way of doing this is to use the snow spectacles of the Greenlanders, which are cut out of wood so as to exclude all light whatever, except what enters through a circular aperture the size of the pupil, and directly in front of it.¹ A cast should be taken in plaster of Paris from the part of the face to which they are to be applied, to enable the artist to cut them of a proper shape; and when finished they should be lined with black velvet.

The last requisite for accurate microscopical observation is steadiness in the microscope, and a steady and comfortable position for the observer. The first is easily attained. The second may be accomplished by the observer resting his doubled arms upon a stool or frame nearly the height of the eye-glass of the microscope, but unconnected with it, while his chin rests either upon his arms or upon his breast.

When all these means and precautions fail in unravelling a mysterious structure, we have often derived advan-

On Test
Objects.

¹ In the snow spectacles a long narrow slit is used to enable the wearer to look on each side of him. An interesting account of the great value of these spectacles, by the celebrated Professor Blumenbach, will be found in the Edinburgh Phil. Journal, vol. viii. p. 261.

On Test Objects. tage, in the case of lined objects, by looking through cylindrical lenses or good prisms; the length of the cylinder, or the refracting edge of the prism, being at right angles to the lines. Narrow slits may also be used with advantage next the eye; but in all these cases, while we improve and give a finer definition to the lines and the spaces between them, we deteriorate vision for other parts of the structure.

CHAP. VII.—ON TEST OR PROOF OBJECTS FOR TRYING THE PERFORMANCE OF MICROSCOPES.

Test objects.

This class of objects, and their application to the microscope, we owe to Dr Goring; and to their introduction we must ascribe much of the rapid improvement which this instrument has undergone. The finest test-objects are the scales of butterflies and moths, which were suggested to Dr Goring by the following passage in Leewenhoeck. "If we examine the wings of this creature (the silk-worm moth) by the microscope, we shall find them covered with an incredible number of feathers (scales), of such various forms, that if an hundred or more of them were to be seen lying together, each would appear of a different shape. To show more clearly this wonderful object, I caused eight feathers to be delineated, for I do not remember that I ever saw them of so curious a make in any flying insect.

"Although the microscope, by which these feathers were drawn, represented objects very distinctly, *the limner could not through it see the ribs or streaks in each feather until I pointed them out to him*; therefore, I put into his hands a microscope which magnified objects almost as much as that by which the silk worm's thread was drawn, desiring him to give the figure of that feather which through it he could see the most distinct."¹

From this passage, Dr Goring naturally inferred, that there were some peculiar properties in the lines on the feathers and scales of insects, which rendered them more difficult to be discovered than other microscopic objects; and hence he discovered their properties as *test* or *proof* objects for trying the penetrating powers of microscopes. Mr Pritchard regards the *penetrating* power of a microscope as dependent on its angle of aperture, and its *defining* power as in the inverse ratio of the quantity of chromatic and spherical aberration. When the angle of aperture was less than a certain quantity, he found that the lined structure of the scales could not be rendered visible, however perfect the instrument was. The following is his list of test objects, arranged in relation to *penetrating* and *defining* power. Several of these are represented in Plate CCCLXII.

I.—*Penetrating Power.*

Sect. I. *Easy.*

1. *Petrobius Maritimus*, scales of, fig. 1.

2. *Lepisma Saccharina*, scales of.

Sect. II. *Standard.*

1. *Morpho Menelaus*, feathers of, fig. 2.

2. *Alacita Pentadactyla*, feathers of the.

3. *Alacita Hexadactyla*, feathers from the body of it.

4. *Lycænæ Argus*, feathers of the.

5. *Tenea Vestianella*, or clothes moth, feathers from under ends of the wing, fig. 3.

- Sect. III. *Difficult.*
1. *Pieris* or *Pontia Brassica*, or cabbage butterfly, feathers from the, fig. 4, 4a, 4c.
 2. *Podura Plumbea*, scales from the, fig. 5, 6, 7, 8, 9, 10, 11.

II.—*Defining Power.*

1. Hair of the common mouse, fig. 12–15.
2. Hair of the bat genus, fig. 16, 17.
3. Leaf of the moss *Hypnum*, species unknown.
4. Spotted scales of the *Lycænæ Argus*, fig. 24.

Besides these test objects, which are copied from Mr Pritchard's drawings in the Microscopic Cabinet, we have added from the same source the following interesting objects:

1. A hair from the larva of the common *Dermestes*, fig. 18.
2. A white hair from a young cat, fig. 19.
3. The hair of a Siberian fox, fig. 20.
4. The hair of a common caterpillar, fig. 21.
5. A scale from the under side of the wing of the blue butterfly, the *Lycænæ argus*, fig. 22.

In some of the preceding figures of the lined proof objects the reader will perceive diagonal or oblique lines, as in fig. 9, 10, different from the longitudinal ones seen in fig. 1, 2, 3, 4, &c. These lines are reckoned more difficult to be seen than the longitudinal ones; and Dr Goring has mentioned those on the scales of the white-cabbage butterfly as a difficult test object. Mr Potter, who has seen these diagonal lines, mentions also his having observed them on the scales of the wing of the small house-moth. As the nature of these oblique lines is far from being understood, and as their real existence is in our opinion questionable, we shall lay before our readers Mr Pritchard's observations on those observed in the scales of the *Podura plumbea* and *Pieris brassica*.

"In the foregoing account," says he, "of the different scales from the wings and bodies of insects, the design has been to give their *appearances* under microscopes or engiscopes without in the least determining their actual structure. When it is considered that these lines are less than the twenty thousandth of an inch distant, it must be allowed there is some difficulty in accurately determining their construction. The *Morpho menelaus* and *Lepisma saccharina* are of sufficient size to distinctly perceive they are composed of two delicate tissues with longitudinal cords (probably tabular) disposed between them; but in the two delicate ones, the subject of these remarks, we perceive other systems of lines disposed obliquely; and as they are extremely delicate, it becomes a question whether they actually exist, or whether they are appearances produced under certain modifications of the illumination. As there is only one set shown at a time, and I have never been able to see them in the decided way of the longitudinal lines, I have been induced to consider them as appearances only, and not real lines. To determine this point, it became necessary to ascertain the cause that would produce such an effect; and it immediately occurred to me that these oblique lines were occasioned by the disposition and pressure of the superambient scales, in the same manner as the watering or wavy appearance communicated to corded silks and moreens by the pressure of two pieces passed between rollers.² In examining the

¹ Select Works, p. 63.

² I have since examined the *Petrobius Maritimus* as an opaque object, which confirms this view of the nature of the oblique lines on its scales.

On Test Objects. scales of the *Pieris brassica* under a deep power and large angle of aperture, I found them broad in some parts and almost invisible in others; and the same appearance presented itself in the curved lines on the scale of the *Podura plumbea*, some idea of which may be obtained by examining figs. 9 and 10 of Plate CCCLXII.

"The motive that has induced me to offer the above remark is, that it may lead to a complete investigation of the subject. What is here given is merely the crude idea that presented itself in the course of their examination as proof-objects."¹

Dr Goring has published, in the *Journal of the Royal Institution*, vol. xxii. and also in the *Micrographia*,² many interesting observations on lined objects, of which it is necessary to give some account. In order to explain the effects of aperture on lined objects, he has represented in the seven circles shown in fig. 23, Plate CCCLXII. the different appearances of a portion of the scale of the *Morpho menelaus*, shown in fig. 1, produced by increasing the aperture. He used a triple achromatic object-glass nine tenths of an inch focus, and half an inch in aperture, with a negative eye-piece of one fourth of an inch.

No. 1. shows the appearance of the scale when the aperture was one tenth of an inch, not a vestige of lines being visible.

No. 2. Aperture three twentieths; Dr Goring fancied he saw indications of lines or scratches.

No. 3. Aperture one fifth; traces of irregular scratches seen.

No. 4. Aperture three tenths; nascent lines recognised by a practised eye, like an aggregation of dots, but interrupted and broken.

No. 5. Aperture four tenths; the lines resolved, but not fairly. They are very faint, and seem rugged, as if still composed of dots and points.

No. 6. Aperture five tenths; the full aperture of the lens. The lines appear in their true character, as if drawn by a pen with some blue pigment on light-violet coloured paper.

No. 7. Same aperture. When the object is turned one fourth round, the cross striæ become perceptible.

Our limits will not permit us to give Dr Goring's excellent observations on the lines of the *Pontia brassica*, as seen also with apertures of different sizes in a reflecting microscope. With a well-figured metal, three tenths of an inch focus, and an angle of $55\frac{1}{2}^\circ$ aperture, the lines and cross striæ he found never to be resolved into dots and points, but to appear in what he supposes to be their proper character. "The two sets of diagonal lines," he remarks, "will be shown with a force and effect which will leave no doubt of their existence in the mind of a candid observer; the various lines, the longitudinal, the cross striæ, and the two sets of diagonals, being all observable successively by a slight change of illumination, though we can scarcely see two of the systems well at the same instant."³

Dr Goring elsewhere observes,⁴ that the reflecting microscope invariably shows the diagonal lines on the *brassica* as distinct as the eye sees the ruled lines on a copy-book; that in some "pet scales" one of the systems of oblique lines may be seen by looking into the instrument directly, and the other by looking into it obliquely, without any alteration in the illumination;⁵ and that if one instrument shows the lines dotted, broken, interrupted, or ragged, while another shows them clearly made out as veritable lines or stripes drawn with a pen and ink, the latter is the best.⁶

Notwithstanding these repeated decisions of Dr Goring, he seems, in an earlier part of his volume,⁷ to have had

some misgivings on the subject. In speaking of the lined tests, he says, "*There is an inexplicable mystery about them, for if their lines are in reality produced on the same principle as those of micrometers, why are they not as easily seen?*" No penetrating power or large angular aperture is requisite to bring out the lines on a micrometer, though divided nearly as finely as ordinary tests, to the extent perhaps of 10,000 in an inch." These observations are just and philosophical, and we would add only a single observation in support of them, that Dr Wollaston made platina wires the 18,000th of an inch in diameter, and saw them distinctly; and we venture to say, that in no instrument whatever would such lines appear either dotted or ragged.

Such was the state of this subject when these lined objects were examined by Sir David Brewster, both in reference to their action upon light when examined by the naked eye, and when placed under the microscope as test objects. Having been occupied for several years in a series of analogous observations on the lines which apparently separate the component fibres of the crystalline lenses of animals, he was familiar with the class of optical illusions which interfere with the accurate development of such structures.

Upon exposing the finest lined objects to a bright light, and excluding as much as possible all other extraneous rays, he saw distinctly the fringes of colour produced by interference; and on measuring the angular distances of the first red fringe from the light, he found that the distance of the lines, or rather the diameter of one black line and half the bright space between the lines, varied from the 10,000th to the 22,000th of an inch. Hence, if we take the black lines and their intervals to be equal, the diameter of each will vary from about the 13,000th to the 29,000th of an inch.

Although these apparent lines give colours by interference, exactly like the analogous lines in the laminae of the crystalline lens, yet neither of them are *real lines*, as decided upon by Dr Goring. With small apertures the lines in the crystalline lens appear *dotted, interrupted, uneven, and ragged*, and exhibit, in short, all the general phenomena of the lines on proof objects; but with a good microscope and a large aperture, we discover the true secret of all these appearances. They are not lines, but a succession of teeth arranged in lines; and from the great number of lines forming the sides of the teeth, they appear dark. Each fibre, in short, has teeth on each side of it,⁸ and the teeth of one fibre lock into the spaces between the teeth of the adjacent fibres. When we trace these fibres towards the pole to which they converge, they become smaller and smaller, the teeth diminishing in the same proportion, so that they become as difficult, and finally more difficult to resolve than the lines in the proof objects.

After a laborious examination of the lined tests, and the use of every optical resource which he could command, Sir David Brewster has found that the mysterious lines on these test objects are only apparent lines, being composed of a succession of interlocking teeth, by which the fibres to which they are attached form that delicate film which composes the scale of a moth. We now see the source of all the perplexities which have beset this class of observations. We understand why such lines are not seen so distinctly as the real lines on micrometers, and the dots and the raggedness are all explained. In the lenses of quadrupeds the teeth of the fibres are not round like those of fishes, but are often sharp pointed and extremely short, like a jagged line, or a line with

On Test Objects.

¹ *Microscopic Cabinet*, p. 160, 161.

² *Hall*, 159, &c.

³ *Micrographia*, p. 163.

⁴ *Micrographia*, p. 130 and 144.

⁵ *Ibid.* p. 102, note.

⁶ *Ibid.* p. 104.

⁷ *Micrographia*, p. 44.

⁸ See *Phil. Trans.* 1830.

On Test
Objects.

Diagonal
lines ex-
plained.

points projecting from it. In like manner, the separation of the teeth is much more distinct in some of the lined objects than in others. See fig. 24, in which we have given a rude representation of the lines.

With regard to the diagonal or oblique lines, which have been such a source of perplexity to microscopical observers, we have little hesitation in pronouncing *those which we have seen* to be optical illusions from the accidental *alignement* of the sides of the teeth in different grooves, when similarly illuminated by oblique rays. When the scales are immersed in diluted sulphuric acid, we have never seen the diagonal lines. When the sulphuric acid is too strong, the scales curl up, and often in this state exhibit the lines very beautifully. We have observed diagonal lines singularly developed in the laminae of the crystalline, and clearly arising from the interference of the rays acted upon by the lines on one side of the lamina, with the rays acted upon by the lines on the other side, and therefore we have been the more confirmed in our opinion. As we have not had the advantage, however, of using any of the fine reflecting microscopes with which Dr Goring observed the oblique lines so distinctly brought out, it is still with considerable diffidence that we place our conclusions in opposition to so direct and distinct an observation, made by such skilful and experienced observers as he and Mr Pritchard.¹

With the view of arriving at a just decision respecting the nature of the lines, Sir David Brewster endeavoured to ascertain the disposition of the colouring matter on the scales. Owing to the great brightness of the lines on the black scales, especially near their root, he was at first disposed to infer that, at least in these scales, the colouring matter was arranged along the black lines, the particles being more readily detained in their places by the edges of the teeth. He has found, however, that in other scales the colouring matter lies also along the bright lines; and it is only when this colouring matter is removed, or its effect masqued, by removing the refraction at its surface by immersion in a fluid, that the lines of proof objects are developed with perfect distinctness.

Sir David Brewster has made an attempt to count the number of scales and teeth in the wing of a brown moth, or in one superficial inch, the area of the two surfaces of each wing. He supposes, of course, all the scales to be the same in size and structure, and he finds that there are

Scales 158,400

Teeth 19,800,000,000

or nineteen thousand eight hundred million.

CHAP. VIII.—ON MICROSCOPIC OBJECTS.

Microscop-
ic objects.

In the preceding chapter we have already described some of the most interesting objects for microscopical observation. Every department of nature is full of objects, from the examination of which the most important discoveries may be expected; but though the zealous observer can never be at any loss for subjects of research, it is desirable to know what has been done by our predecessors, and what trains of inquiry are most likely to prove of general interest. There are subjects of microscopic inquiry which are closely connected with the most interesting parts

of physiology; and even geology itself, conversant with the grandest subjects of research, has recently been illustrated by the aid of the microscope.

M. Ehrenberg, to whom we are indebted for so many important discoveries respecting the organisation of infusorial animalcules, has lately made the most remarkable discovery of *infusorial organic remains*. These remains are the siliceous shells of animalcules belonging to the division Bacillaria, and form strata of Tripoli, or poli-schiefer (polishing-slate), at Franzenbad, in Bohemia.² M. Ehrenberg has still more recently discovered them in the semi-opal found along with the polishing-slate in the tertiary strata of Bilin, in the chalk flints, and even in the semi-opal or noble opal of the porphyritic rocks.³ The size of a single individual of these animals is about $\frac{1}{200}$ th of a line, or $\frac{1}{3456}$ th of an inch. In the polishing-slate from Bilin, in which there appear to be no vacuities, a cubic line contains, in round numbers, 23 millions of these animals, and a cubic inch contains 41,000 millions of them!

The weight of a cubic inch of the polishing-slate is 270 grains. There are, therefore, 187 millions of these animals in a single grain, or the siliceous coat of one of these animals weighs the 187 millionth part of a grain!

In Plate CCCLXII. figs. 24 and 25, we have given representations of these singular microscopic objects, as seen by Ehrenberg.

Another example of the value of microscopical observations may be drawn from the discovery of the teeth of the fibres, which compose the crystalline lenses of almost all the crystalline lenses. The crystalline lens is composed of innumerable fibres of nearly the same length, each of which tapers from its middle to its two extremities, where it comes to the sharpest point. The sides of each of these fibres are furnished with teeth like those of a watch-wheel, and the teeth of the one lock into those of the adjacent ones, as shown in fig. 28, Plate CCCLXII. When the power is small, or the microscope not good, or the laminae too thick and not nicely detached, each row of interlocking teeth appears as a dark line, sometimes as sharp as a black line drawn upon paper with a pen. Sometimes the lines appear rough and ragged, and as the fibres become less and less in approaching the poles, the black lines are as difficult to resolve into teeth as the lines on test-objects already described. The following measures, taken by Sir David Brewster, will show what a wonderful structure in the eye has been thus disclosed to us by the microscope. The calculations refer to the lens of a cod, four tenths of an inch in diameter.

Number of fibres in each lamina or spherical coat.... 2,500

Number of teeth in each fibre..... 12,500

Number of teeth in each spherical coat..... 31,250,000

Number of fibres in the whole lens..... 5,000,000

Number of teeth in the lens..... 62,500,000,000

or the lens of a cod contains five millions of fibres, and sixty-two thousand five hundred millions of teeth; and if we reckon the curved end of the tooth as one surface, each tooth will have six surfaces,⁴ which come into contact with the corresponding surfaces of the adjacent tooth, so that the number of touching surfaces will be *three hundred and seventy-five thousand millions*;⁵ “and yet this little sphere of tender jelly is as transparent as a drop of the purest water, and allows a beam of light to pass across these al-

¹ Mr Pritchard informs us that the diagonal lines or cross striæ are most easily seen in the scales from the wing of the *Euplecta limniaca*, and in the blue scales from the *Papilio Paris*, where they “are strongly and easily developed under a power of from 100 to 200 times.” In speaking of the ordinary lines, Mr Pritchard remarks, that these lines or “markings,” with his best instruments, “appear detached like short hairs or spines covering the delicate tissue of the scale. This latter appearance is correct, the prominent portions of the lines which have escaped the pressure of those of the surrounding scales being in a plane above the other portions of the lines.” This opinion of the structure of the lines, published in 1835, is not repeated in the *Micrographia*, published in 1837, where Dr Goring decides that they are real lines. See *List of 2000 Microscopic Objects*, p. 10. Lond. 1835.

² Poggendorff's *Annalen der Physik*, 1836, No. V. p. 225.

⁴ This includes the concave surface between two adjacent teeth.

³ *Ibid.* No. VI. p. 464.

⁵ *Philosophical Transactions*, 1833, p. 329.

On Mi-
croscopic
Objects.

Fossil in-
fusoria.

Fibres of
teeth in
the crystal-
line lens.

Microscopic Objects. most innumerable joints without obstructing or reflecting a single ray!"

Microscopic cavities in gems. There is another class of objects of extreme interest, which Mr Pritchard has omitted to notice, and the development of which called forth all the resources of optical knowledge and practical experience with the microscope. These objects are the microscopic cavities in minerals, containing two fluids unknown to the chemist, groups of crystals, floating balls, and exhibiting actual chemical operations going on in these minute laboratories when exposed to changes of temperature. These various phenomena have been described and represented in drawings, in two papers by Sir David Brewster, published in the Transactions of the Royal Society of Edinburgh. In some of the precious stones, particularly in diamond, garnet, &c. these cavities are perfect spheres; but, owing to the great refractive power of the gem, they appear completely black and opaque, though the microscope describes a small spot of light in their centre, which is the pencil of light which they refract. These spherical cavities, and this central spot, are the finest objects for examining the aberration of lenses and specula, and are infinitely preferable to the reflected patches of light from small spherules of quicksilver. Dr Goring has observed spherical cavities or air-bubbles in fluids, and, with his usual ingenuity, recognised their utility for indicating the effects of aberration. Those which we have used in the gems are, however, permanent instruments of much greater utility, not only from our being able to use the same bright spot with all instruments and on all occasions, but from the dark ring round the bright spot being incomparably greater in the gems than in fluids.¹ Representations of some of the cavities in fluids are given in Plate CCCLXII. fig. 29, 30, 31. Fig. 29 shows the cavities containing the two new fluids, which will not mix, though in the same cavity. The little circle is the bubble either of gas or of vacuity. The fluid round it is a highly evaporable fluid, and the fluid in the angles and ends of long cavities is a thick and unevaporable fluid, which indurates when exposed to the air. Figs. 29 and 30 are beautifully formed cavities in topaz.

Our limits will not permit us to pursue this subject farther, and we shall conclude the article with a very brief selection of microscopic objects from Mr Pritchard's admirable little pamphlet, entitled a List of 2000 Microscopic Objects.

1. INSECTS.—Eggs, wings, tongues, antennæ, and scales of.

Eyes of, Agrion, 12,000 eyes; Bombyx Mer, 6236 eyes; Phalæna cossus, 11,300; Scarabæus, 3180; Hawk-moth, 20,000; Libellula, 12,544; Melalontha, 8820; Mor-della, 25,088; Papilio, 17,000.

2. HAIRS OF ANIMALS. Hair of an infant, Ornithorynchus, mouse, bat, bee, Acilius canaliculatus, Melecta punctatus, Siberian fox, spider, wing of Tipalis, stag-beetle, white cat, dormouse, dermestes, caterpillar, badger, ant-eater, civet cat.

3. SCALES OF INSECTS. Podura plumbea, Pontia brassica, Pieris brassica, Parnassus Apollo, Atlas moth, diamond-beetle, Euplœa limniace, house-moth, Lepisma saccharina, 10-plumed moth, 20-plumed moth, Morpho Menelaus, Papilio Apollo, Papilio Paris, Urania leilus, privet moth.

4. CIRCULATION IN PLANTS, or *Cyclosis*. Nitella hyalina, Nitella translucens, Chara vulgaris, Caulinia frigalis, Hydrocharis or frog-bit in the stipulæ of the leaves and the ends of the roots, Tradescantia virginica or spiderwort in the filaments around the stamina, Senecio vulgaris or groundsel in the hairs surrounding the stalks and flowers.

5. CIRCULATION IN ANIMALS. In the arachnoida or spider tribe at the joints of the legs, Peria viridis and Semblis bilineata on the antennæ and wings when they have just emerged from the chrysalis, larva of the Ephemera, larva of Hydrophilus, small Dysticus, Agrion puella, Libellula, round Lynceus, fresh-water shrimp, water-hog (Oniscus), Ligia, water-flea (Daphnia pulex). (See Pritchard's Microscopic Illustrations, and Microscopic Cabinet.)

6. CIRCULATION IN ZOOPHYTES. Mr Lister has discovered a circulation resembling that in plants in some of the polypiferous zoophytes, as the Tabularia indivisa, Sertulariæ, Campanulariæ, Plumulariæ, &c.

7. CRYSTALS. For an account of various interesting microscopic phenomena observed by H. F. Talbot, Esq. of Lacock Abbey, we must refer the reader to a series of interesting papers in the recent numbers of the London and Edinburgh Philosophical Magazine. The oxalate of chromium and potash dissolved in water and rapidly crystallised is a fine object. In polarised light the most splendid object is the Faro Apophyllite when the prisms are complete, as represented by Sir D. Brewster in a coloured drawing in the Edinburgh Transactions, vol. ix. p. 317, plate xxi. fig. 1.

	Size.
8. ANIMALCULES. Monas Termo,	18,000th of an inch.
Monas atomus,	4000th of an inch.
Monas volvox,	3456th to 1728th of an inch.
Volvox globator,	found in stagnant water, 30th of an inch.
Vibrio, bipunctatus,	200th of an inch.
Vibrio spirillum,	like a screw, 2000th to 1000th of an inch.
Vibrio glutinis. ²	
Kolpoda cucullus,	28th of an inch.
Cercaria podura.	
Cercaria viridis.	
Cercaria hirta.	
Leucophrys fluida,	400th of an inch.
Trichoda vulgaris,	1200th to 240th of an inch.
Trichoda longicauda.	
Vorticella polymorpha.	
Vorticella convallaria.	
Vorticella senta,	100th of an inch.
Vorticella rotatoria. ³	

The reader will find beautiful drawings and full descriptions of these and many other animalcules in Mr Pritchard's interesting work entitled The Natural History of Animalcules, London, 1834. In the Microscopical Illustrations of Mr Pritchard and Dr Goring, and in the Microscopic Cabinet by the same authors, he will find every thing that he desires respecting microscopic objects.

(N. N. N.)

¹ The ratio between the diameter of the dark sphere and of the small luminous spot gives a measure of the refractive power of the solid or fluid.

² Figured by Dr Goring in the Microscopic Cabinet.

³ The Rotifer vulgaris. See Microscopic Cabinet, chap. vi.

Midas
||
Middle
Island.

MIDAS, in fabulous history, a famous king of Phrygia. Bacchus, having been received by him with great magnificence, offered, out of gratitude, to grant him whatever he should ask. Midas desired that every thing which he touched should be changed into gold. Bacchus consented; and Midas, with extreme pleasure, found everywhere the effects of his touch. But he had soon reason to repent of his folly; for, when he wanted to eat and to drink, the aliments no sooner entered his mouth than they were changed into gold. This obliged him to have recourse to Bacchus again, to beseech him to restore him to his former state; upon which the god ordered him to bathe in the river Pactolus, which thenceforward had sands of gold. Some time afterwards, being chosen judge between Pan and Apollo, he gave another instance of his folly and bad taste, in preferring Pan's music to Apollo's; upon which the latter, being enraged, provided him with a pair of ass's ears. This Midas attempted to conceal from the knowledge of his subjects; but one of his servants having seen the length of his ears, and being unable to keep the secret, yet afraid to reveal it from apprehension of the king's resentment, opened a hole in the earth, and after he had whispered there that Midas had the ears of an ass, he covered the place as before, as if he had buried his words in the ground. On that place, however, as the poets mention, there grew a number of reeds, which, when agitated by the wind, uttered the same sound which had been buried beneath, and published to the world that Midas had the ears of an ass. Some explain the fable of the ears of Midas, by the supposition that he kept a number of informers and spies, who were continually employed in gathering and retailing every seditious word which might drop from the mouths of his subjects. Midas, according to Strabo, died of drinking bull's blood hot, a potion which he is said to have taken in order to free himself from the numerous evil dreams which continually tormented him. According to some, this personage was son of Cybele, and built a town, which he called *Ancyra*.

MIDDELBURG, a circle of the province of Zealand, in Holland, consisting of the island of that name, which is separated by the Elloe water from South Beveland; it is divided into six cantons, and contains 30,000 inhabitants. The capital is the city of the same name, nearly in the centre of the island; it was once fortified, but is now with its walls converted into pleasing promenades. It is well built, and has twelve churches, one of which, the New Church, has a lofty tower, serving as a useful sea-mark. In 1830 it contained 14,700 inhabitants, viz. 6469 males and 8231 females. The city has manufactories of linen and woollen cloth, and is celebrated for its chocolate. It is connected by water with the West Scheldt, but its shipping operations have been on the decline, and but slightly revived since the return of peace. This city was the birth-place of the celebrated jurist Bynkershoek. Long. 3. 32. 10. E. Lat. 51. 30. 6. N.

MIDDELTON, a market-town of the county of Lancaster, in the hundred of Salford, 190 miles from London and seven from Manchester, on the road to Rochdale. The inhabitants are chiefly employed in the different branches of the cotton manufacture. It is a parish of itself, and has a market, which is held on Saturday. The inhabitants of the town were, in 1801, 3265; in 1811, 4422; in 1821, 5809; and in 1831, 6903; but at the last census the whole parish, which comprises also seven other chapelries or townships, contained 14,370 inhabitants.

MID-HEAVEN, the culminating point of the ecliptic, or that in which it cuts the meridian.

MIDDLE ISLAND lies off the south coast of New Holland, in longitude 123. 10. east, and latitude 34. 7. south. There is another small island of this name in the strait between the islands of Billiton and Banca, which it divides

into two, namely, on the west, Gaspar's Strait, and on the east, Clement's Strait. It is also the name of a small island in the narrowest part of the Straits of Sunda, opposite to Hog's Point, in Sumatra, called also Thwart the Way. Long. 105. 43. E. Lat. 5. 55. S.

MIDDLEBURG, one of the Friendly Islands, in the South Sea. See POLYNESIA.

MIDDLEBURGH, a small island, about ten miles in circumference, situated off the north-western extremity of Ceylon.

MIDDLEHAM, a market-town of the north riding of the county of York, in the wapentake of Hang West, 232 miles from London. It has the remains of an ancient royal castle, where King Richard III. was born, and Edward IV. died. The church is large, and was formerly collegiate. The inhabitants, who are chiefly employed in the manufacture of woollen goods, amounted in 1821 to 880, and in 1831 to 914. A market is held here on Monday.

MIDDLESEX, an English county, and, though in extent one of the least, yet, as containing within it the metropolis of the British empire, with its numerous population, its extensive wealth, and its repositories of art and science, and being the theatre of the most interesting historical and political transactions, naturally attracts to it the attention of all who are connected with the united kingdoms.

This county is bounded on the north by Hertfordshire; on the west by Buckinghamshire; on the south by Surrey, and at the eastern point by a small portion of Kent; and on the east by Essex. Its general figure is quadrangular, but rendered very irregular by the course of the rivers Thames, Coln, and Lea, which bound it on three sides, and by a considerable projection into Hertfordshire on the north. Its greatest length is twenty-three and its greatest breadth seventeen miles. Its square contents are estimated at 285 miles, or 182,400 statute acres.

According to the census of 1831, the whole number of inhabitants was 1,358,330, of whom 631,410 were males and 726,920 were females. These composed 314,039 families, of whom 9882 were chiefly occupied in agriculture; 173,822 were chiefly occupied in trade, manufactures, and handicraft; and the remainder, 130,335, were not comprehended in either of these two classes.

A more minute classification is as follows:—

Males under twenty years of age.....	358,521
Occupiers of land, employing labourers.....	1,050
Occupiers of land, not employing labourers.....	490
Labourers employed in agriculture.....	11,376
Employed in manufacture, or in making manufacturing machinery.....	11,064
Employed in retail trade, or in handicraft, as masters or workmen.....	163,220
Capitalists, bankers, professional and other educated men.....	49,457
Labourers employed in labour other than agricultural.....	79,735
Other males, twenty years of age, not servants.....	22,549
Male servants, twenty years of age.....	19,578
Male servants under twenty years of age.....	5,923
Female servants.....	87,554

The baptisms of 1830 were, males 167,444, of females 165,683; the burials in the same were, of males 148,390, and of females 141,529. The marriages were 13,295. The illegitimate children born in the same year were, of males 526, of females 380.

The proportion of burials to the whole population, which in 1801 was one in thirty-one, was in 1830 one in forty-two. The amount expended for the relief of the poor had varied but little during the ten years from 1820 to 1830. In the first of these years it amounted to L.625,665, and in the last to L.681,567.

Middle-
burg
|
Middlesex.

Middlesex. The annual value of the real property of the county, as assessed in the year 1815, was L.5,595,337. The increase of the population is shown by the several decennial enumerations to have been as follows, viz. in 1801, 818,129; in 1811, 953,276, being an increase of seventeen per cent.; in 1821, 1,144,531, being an increase of twenty per cent.; and in 1831, 1,358,200, being an increase of nineteen per cent. The whole increase in the thirty years has been sixty-five per cent. If the same rate of increase should *Middlesex.* continue till 1841, which there seems no reason to doubt, the county will then have doubled its inhabitants in about the period of forty or forty-one years.

The county is divided into six hundreds, and the three cities of London within the walls, London without the walls, and Westminster. The most populous of the hundreds, that of Ossulstone, is formed into four divisions.

Cities or Hundreds.	Families.	Males.	Females.	Total.
Edmonton hundred.....	4,801	12,969	13,961	26,930
Elthorne ditto.....	4,224	9,998	10,093	20,091
Gore ditto.....	2,049	5,697	5,618	11,315
Isleworth ditto.....	2,871	6,515	7,053	13,568
Ossulstone.				
Finsbury division.....	34,569	70,641	80,768	151,409
Holborn ditto.....	83,467	154,743	191,512	346,255
Kensington ditto.....	20,179	39,217	48,744	87,961
Tower ditto.....	84,282	168,146	191,718	359,864
Spelthorne hundred.....	3,175	7,325	7,887	15,212
London within the walls.....	11,719	27,327	28,451	55,778
London without the walls.....	15,884	33,413	34,492	67,905
Westminster city.....	46,004	95,219	106,623	201,842
Militia under training.....		200		200
	314,039	631,410	726,920	1,358,330

The places of most note in this county, besides the cities of London and Westminster, are towns which have sprung up from their contiguity or vicinity to the metropolis, and which, in many instances, though forming only suburbs, are to all appearance, and to all practical purposes, parts of the great city. In giving the population, those places in contact with London must be first noticed.

Mary-le-bone parish.....	122,206
Pancras, with its hamlets.....	103,548
Paddington.....	14,540
Bethnal Green.....	62,018
Chelsea.....	32,371
Kensington, with its hamlets.....	20,902
Shadwell.....	9,544
Stepney parish, including Poplar, Blackwall, Limehouse, Mile-end, Old and New Town, and Ratcliffe.....	67,872
Bromley.....	4,846

The other populous places not in contact with the metropolis are,

Hackney, with its hamlets.....	31,047
Islington.....	37,316
Fulham, with Hammersmith.....	17,539
Hampstead.....	8,588
Ealing, including Old Brentford.....	7,783
Tottenham.....	6,937
Enfield.....	8,812
Cheswick.....	4,994
Twickenham.....	4,571
Hornsey, with part of Highgate.....	4,857
Hampton, including the court and Hampton Wick.....	3,992
Hendon.....	3,110
Uxbridge, with Hillingdon.....	6,885
Heston, with a part of Hounslow.....	3,407
Stoke-Newington.....	3,480
Staines.....	2,486
Edmonton.....	8,192
Harrow.....	3,861
Isleworth.....	5,590

The face of this county may be described as a gently sloping tract rising from the banks of the Thames, its

southern boundary, to the hills on the north, none of which rises more than 350 feet above the level of that river, and few attain even that height. In receding from the banks of the stream, the surface is gently undulated, with sufficient slope to secure the necessary drainage. The prospects in the southern division of the county, from the level nature of its surface, are not distinguished by extent or variety; and the eye is only relieved from the fatigue of uniformity, by the numerous buildings, plantations, gardens, and the rich verdure of productive grass fields. Even in the more hilly parts of the county the prospects are far less impressive than those upon the opposite banks of the Thames, or those which are to be seen upon the borders of that river before it enters Middlesex. The best prospects of a rural kind are from the range of hills stretching from Pinner, Stanmore, Elstree, Totteridge, and Barnet, to the forest scenery of Enfield Chase. The Hill of Harrow, a projection from this ridge, is one of the highest points; and the whole of the richly-cultivated valley of Middlesex is comprehended in the view from it.

The original soil on the southern side of the county is of a most sterile kind of gravel; but the vast quantities of manure which have been furnished to it from the extensive cities in its vicinity, have been so spread over the surface, that a most luxuriantly-productive soil of garden mould has been created; and from the same cause it is renewed as rapidly as it becomes exhausted by the crops grown upon it. The northern part of the county generally consists of a soil of clayey loam, which, though rather difficult to plough, is, when properly pulverised, very well adapted for the cultivation of wheat, and has been long celebrated for the excellent quality of that grain which is produced upon it. The table of Queen Elizabeth was regularly furnished with white bread from the wheat grown in the vicinity of Hounslow. In several parts of the county the loamy clay, converted by the addition of cinders, technically called breeze, into bricks, becomes the most profitable application of the soil. This is peculiarly the case where such soil is found in the immediate vicinity of the metropolis, or upon the banks of the rivers or canals that communicate with it. "Round the one-mile stone on the Kingsland Road," says Mr Middleton, "the surface is

Middlesex. lowered from four to ten feet, by the earth having been dug up and manufactured into bricks, over an extent of more than 1000 acres; and it has been levelled, ploughed up, and laid down to grass. It is sufficiently dry, and by the help of town manure is restored again to excellent grass land; though it had previously yielded to the community, through the medium of the brickmakers, upwards of L.4000 per acre on an average of the whole level; but there are a few acres of choice marl earth, which have produced through the same medium L.20,000 per acre."

The greater portion of the land in the county is appropriated to the cultivation of grass, which is converted into hay for the supply of the numerous horses kept in the metropolis. These upland meadows have been gradually extending as the metropolis has increased, so that at present not more than 20,000 acres are under cultivation by the plough. The meadows, however, even those which have been longest laid down in herbage, discover the marks of their having been formerly ploughed. The great consumption of hay in the London markets has induced the most skill to be applied to that particular branch of rural economics which, under the term haymaking, is usually deemed the simplest of all agricultural operations, but which is here managed in so superior a way as to bring to the stack hay of a quality far better than is preserved in the more distant counties. The corn grown in this county is inconsiderable. Upon an average of years, about 10,000 acres are sown with wheat, about 4000 with barley, about 3000 with beans, and about 2000 with pease; some rye is grown, but principally for green food, and scarcely any oats are cultivated. There are fewer sheep and cows kept in Middlesex than in any other county; but of the latter some thousands are maintained solely for the purpose of supplying milk for the consumption of the metropolis. Many pigs are fattened from the offal produced in the vast breweries and malt distilleries of London and its vicinity.

The horticulture of Middlesex, although it does not extend over quite so great a surface as its arable culture, produces a far greater annual return. Exclusively of the gardens attached to the houses of the nobility and gentry, the extent of land appropriated to the growth of fruit is reckoned by Mr Middleton to be 3000 acres, of that devoted to culinary vegetables 10,000, and of that used as nursery grounds and plantations 1500. The same writer estimated the annual value of the productions of horticulture at somewhat more than one million sterling. The gardeners of Middlesex practise a wonderful economy in the raising of crops. The fruit gardeners have what they call an upper and an under crop growing on the same ground at the same time. First, the ground is stocked with apples, pears, cherries, plums, walnuts, &c. like a complete orchard, and called the upper crop. It is secondly fully planted with raspberries, gooseberries, currants, strawberries, and all such fruits, shrubs, and herbs as are known to sustain the shade and drippings from the trees above them without the least injury; this they term the under crop. Some of these gardens have walls which are completely clothed with fruit-trees, such as peaches, nectarines, apricots, plums, and various others, all adapted to the aspect of the wall. In order to increase the quantity of warmth and shelter in autumn, they raise earthen banks of about three feet in height, laid to a slope of forty-five degrees to the sun. On these slopes they plant endive in the month of September; and near the bottoms of them they drill pease from October to Christmas; by this means the endive is preserved from rotting, and, as well as the pease, reaches maturity at an early period. The common routine of the best kitchen gardeners is the following: Soon after Christmas, when the weather is open, they begin by sowing the borders, and then the quarters, with radishes, spinach, onions, and all the other seed crops. As

soon afterwards as the season will permit, which is generally in February, the same ground is planted with cauliflowers from the frames, as thick as if no other crop had then possession of the ground. The radishes, &c. are soon sent to market; and when the cauliflowers are so far advanced as to be earthed up, sugar-loaf cabbages are planted from the before-mentioned seed crops; and daily as these crops are sent to market, the same ground is cropped with celery for winter use. The foregoing rotation is the common practice, but there are many deviations, according to the judgment of the cultivators, the state of the weather, and the demands of the market. Such a system, however, can be pursued only in the vicinity of great cities, the abundant manure of which gives the means of raising vegetable productions in defiance of the inclemency of our northern winters. A species of cultivation of a nondescript kind, partaking of the nature of agriculture and horticulture, is extensively pursued in this county. The ground is ploughed in January and February, and cropped with early pease, which are gathered green in June. The land is then sowed with turnips, which are sold in autumn, when the kind of cabbages called collards are planted, and these three crops are annually raised from the same soil.

Manufactures of every kind may be ascribed to this county, in so far as the best workmen of every description are employed in London for combining, fitting, and finishing all the commodities requisite for the consumption of the metropolis, which is at the same time the seat of government, the temporary residence of the wealthiest subjects of Great Britain, and the greatest sea-port of the empire, but workmen of this kind, forming more than 400 classes, cannot be here so appropriately described as under the article LONDON, to which the reader is referred.

In the more appropriate application of the word *manufacture*, none of importance can be attributed to Middlesex, other than that of silk, which subsists in Spitalfields, and which employs upwards of 5000 males above twenty years of age. In St Mary's parish, Whitechapel, 440 men of that age are employed in sugar-refining. Ship-building, and the various auxiliaries of that art, such as rope-making, sail-making, block-making, anchor-making, and the fabrication of copper sheathing and bolts for ships, with numerous smaller articles, employ a great number of persons. There are manufactories of chemical preparations at Bow, mustard-mills at Staines, copper-works at Harefield, and mills for throwing silk in many places.

The rivers of Middlesex are, the Thames, the Coln, the Brent, and the Lea. The former of these is navigable for barges, along almost its whole extent, to Leachlade in Gloucestershire, within a few miles of its source. The tide is felt as high as Teddington, above which the navigation is performed by penning the water at various locks till a sufficient body is collected, which, by making what is locally called a *flash*, permits the passage of the barges over the obstructions and shoals, which, a few hours after, become again impassable. The picturesque beauties on the banks of this stream are too well known to need a description in this place. The Coln is not navigable. It enters Middlesex from Hertfordshire at the north-western extremity of the county, and falls into the Thames in various channels at considerable distances from each other, having in its course been applied to the working of numerous mills for paper, corn, and other purposes. The Brent, also not navigable, enters the county from Hertfordshire, and joins the Thames at Brentford. The Lea is navigable for barges along its whole course through this county. It enters from Hertfordshire, forms the eastern boundary of Middlesex, and joins the Thames at Limehouse, below London. Besides these natural streams, the artificial one called the New River belongs to this county. The artificial channel in which this stream flows towards London has a very de-

Middlesex. vious course, in order to keep the waters at a due level. It is ultimately received into a spacious reservoir near Islington, whence, by means of pipes, its water is conveyed through the streets of the metropolis to the houses of individuals.

Amongst the public works of this county, the canals deserve notice. These are, the Grand Junction, the Paddington, and the Regent's Canal. The first forms a connection with the whole interior of the kingdom, and the second is connected with it. Through them, internal navigation is conducted to the manufacturing counties, and to the distant ports of Liverpool, Bristol, and Hull, and to the potteries, iron-founderies, and collieries of Staffordshire and Warwickshire. The Regent's Canal surrounds the whole of the northern side of the metropolis, around which it describes a semicircle, commencing at the dock of the Paddington Canal, and terminating at the river Thames at Limehouse. Its principal utility is supposed to be derived from forming the means of conveying coals and other heavy commodities from the river to the more distant parts of the capital without expensive land-carriage. We may here notice two works actually in operation, which may become of vast importance. These are, the railroad from London to Birmingham, which has been considerably advanced, and a similar one to Southampton, already commenced. For another to Bristol an act of parliament has been obtained.

The docks constructed of late years for the facilities of commerce are most extensive and magnificent works, and the warehouses which surround them are wonderful exhibitions of the commercial opulence of this country, having been all completed from the capitals of individuals. The West India Docks contain about sixty acres of water, in which the largest vessels can float. The London or Wapping Docks are of nearly the same extent. The St Catherine's Docks, finished in 1828, can accommodate annually 1400 vessels; and, being near the centre of the trading establishments, are found of vast benefit. The East India Docks are more than thirty acres; and near them is a dock belonging to private individuals (Messrs Wigram and Green), of nearly twenty acres, where the business of ship-building is carried on upon a scale which exceeds that of most of the establishments of the governments of Europe.

The most remarkable edifices of this county are more properly described under the articles LONDON and WESTMINSTER in this work. Beyond the limits of these cities may be noticed the palaces of Hampton Court and Kensington; the Hospital of Chelsea, for invalid soldiers; the Royal Military Asylum; the bridges of Staines, Vauxhall, and Waterloo; Middlesex Hospital; St George's Hospital; Jews' Hospital; and Harrow School. The number of other erections, of a second and third order, are too numerous for recapitulation.

The changes of property have been so rapid in this county, and the taste for substituting fashionable novelty in the room of venerable antiquity has been so prevalent, that very few first-rate seats are to be found, but a vast number of second and third-rate houses, which, if removed from the vicinity of the metropolis, would attract considerable notice. The most remarkable residences are, Bently Priory, Marquis of Abercorn; Bushy Park, the residence of his present majesty when Duke of Clarence; Caenwood, Earl of Mansfield; Chiswick House, Duke of Devonshire; Fulham Palace, Bishop of London; Holland House, Lord Holland; Littleton, Thomas Wood, Esq.; Osterley House, Earl of Jersey; Sion House, Duke of Northumberland; Strawberry Hill, Countess of Waldegrave; Wrotham Park, George Byng, Esq.; Harrow, Lord Northwick; and Sion Hill, Duke of Marlborough.

(See Middleton's *View of the Agriculture of Middlesex*; and Brayley's *Beauties of England and Wales*.)

MIDDLESEX is also the name of four different counties Middlesex in the United States of America, one of which is in Massachusetts, another in Connecticut, a third in New Jersey, and the fourth in Virginia.

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Middle-
wich.

MIDDLETON, DR CONYERS, a celebrated English divine, was the son of a clergyman in Yorkshire, and born at Richmond in 1683. He distinguished himself, whilst fellow of Trinity College, Cambridge, by his controversy with his master Dr Bentley, relative to some mercenary conduct of the latter in that station. He had afterwards a controversy with the whole body of physicians upon the dignity of the medical profession, concerning which he published *De medicorum apud veteres Romanos degentium conditione Dissertatio; qua, contra viros celeberrimos Jacobum Sponium et Richardum Meadium, servilem atque ignobilem eam fuisse ostenditur*. In the course of this dispute much resentment was manifested, and many pamphlets appeared. Hitherto he had stood well with his clerical brethren; but in 1729 he drew upon himself the resentment of the church, by writing a Letter from Rome, showing an exact conformity between Popery and Paganism; as this letter, although politely written, yet attacked Catholic miracles with a gaiety which appeared dangerous to the cause of miracles in general. Nor were his Objections to Dr Waterland's manner of vindicating Scripture against Tindal's *Christianity as old as the Creation*, looked upon in a more favourable point of view. In 1741 appeared his great work, entitled *History of the Life of M. Tullius Cicero*, in two vols. 4to, which is indeed a fine performance, and will probably be read as long as taste and polite literature subsist amongst us. In 1748 he published a Free Inquiry into the Miraculous Powers which are supposed to have subsisted in the Christian Church from the earliest ages, through several successive centuries. He was now attacked from all quarters; but before he took any notice of his antagonists, he supplied them with another subject, in an Examination of the Lord Bishop of London's Discourses concerning the Use and Extent of Prophecy. Thus Dr Middleton continued to display talents and learning, which are highly esteemed by men of a free turn of mind, but by no means in a method calculated to invite promotion in the clerical profession. In 1723 he was chosen principal librarian of the public library at Cambridge; and if he rose not to a high station in the church, he was at least in easy circumstances, which permitted him to assert a dignity of mind that is often forgotten in the career of preferment. He was one of the best writers of his age; and he displays a degree of skill and beauty in the structure of his long sentences, which has but rarely been equalled. He died in 1750, at Hildersham, in Cambridgeshire, an estate which he had purchased; and in 1752, all his works, except the life of Cicero, were collected in four vols. 4to. A second edition, in five vols. 8vo, was published in 1755.

MIDDLETON, *Sir Charles, Island*, one of the Fejee Islands, in the South Pacific Ocean. It is fertile, and situated in long. 181. W. lat. 17. 2. S.

MIDDLETON CHEYNEY, a town of the county of Northampton, in the hundred of King's Sutton, seventy miles from London. It is situated in a fertile district on the borders of Oxfordshire, and contained a population in 1801 of 1153, in 1811 of 1172, in 1821 of 1398, and in 1831 of 1415 persons.

MIDDLEWICH, a town of the county of Chester, in the hundred of Northwich, 166 miles from London. It is situated between the rivers Wheelock and Dane, which unite below the town and fall into the Wever; and it has also a canal communication with the Mersey at Runcorn. It has celebrated brine springs of great strength, from which abundance of culinary salt is made, and conveyed with facility to Liverpool. Of late years a branch of the cotton

Midhurst manufacture has been established here. The market is held on Tuesday. The population of the town amounted in 1801 to 1190, in 1811 to 1232, in 1821 to 1212, and in 1831 to 1325; but the whole parish, at the last census, contained 4782 inhabitants.

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Midwifery.

MIDHURST, a town of the county of Sussex, in the hundred of Westbourne and rape of Chichester, fifty-one miles from London. It is situated on the river Arun, and adjoining to it is the magnificent park of the Lords Montague, and the remains of the fine mansion, Cowany House. It is an ancient borough, and returned two members to parliament; but one has been taken from it by the reform act. The population amounted in 1801 to 1073, in 1811 to 1256, in 1821 to 1335, and in 1831 to 1478. There is a market on Thursday.

MIDIAN, or MADIAN, in *Ancient Geography*, a town on the south side of Arabia Petraea, which was so called from one of the sons of Abraham by Keturah.

MIDNAPOOR, a district of Bengal, in the province of Orissa, containing an area of 6102 square miles, and about a million and a half of inhabitants. The bulk of the people are Hindus, but there is a greater proportion of Mahomedans than in most other parts of India. Two thirds of this extensive district consists of a jungle swarming with noxious animals, and exceedingly unhealthy, although the land is rich and fertile. This district was formerly ceded to the East India Company in 1761. Having been long the scene of warfare between the Afghans, Moguls, and Mahrattas, it contains a great number of small forts, which serve as a refuge for robbers, from which they frequently annoy the inhabitants. The country produces abundance of grain, sugar, tobacco, cotton, and indigo. Its principal towns are Midnapore, Jellasore, Piply, and Narraingur. Midnapore, the capital, formerly possessed a fort, which has been converted into a criminal prison. It is seventy miles west by south from Calcutta. Long. 87. 25. E. Lat. 22. 25. N.

MIDSHIP-FRAME, a name given to that timber, or combination of pieces formed into one timber, which determines the extreme breadth of the ship, as well as the figure and dimensions of all the inferior timbers.

MIDSHIPMAN, a sort of naval cadet, appointed to second the orders of the superior officers, and to assist in the necessary business of the vessel, either on board or on shore.

MIDWIFERY, the art of assisting women in parturition. In a more extended sense, it is understood to comprehend also the treatment of the diseases of women and children. It is obvious that the obstetrical art must have been almost coeval with mankind; but in Europe it continued in a very rude state till the seventeenth century; and even after physic and surgery had become distinct professions, it remained almost totally uncultivated.

It is a curious fact, that in China the very reverse of this has taken place. In that empire, both physic and surgery are still in a state of degradation; but for some hundreds of years, the art of midwifery has, it is said, been practised by a set of men destined to the purpose by order of government. These persons, who hold in society the same rank which lithotomists formerly did in this country, are called in whenever a woman has been above a specified number of hours in labour, and employ a mechanical contrivance for completing the delivery without injury to the infant. A proportional number of such individuals is allotted to each district containing a certain population. It is said, that the Chinese government was led to make this provision for alleviating the sufferings of women in childbirth, in consequence of a representation, that annually many women died undelivered; and that in the majority of cases the cause of obstruction might have been removed by very simple mechanical expedients.

Both Sir George Staunton and Mr Barrow were ignorant of this fact; and the latter in particular expressly mentions that there are no men-midwives in China; but we have learned the facts above stated from a gentleman who resided upwards of twenty years as surgeon to the British factory at Canton, and who had both the ability and the inclination to make himself acquainted, during the course of so long a residence, with all the customs and prejudices of the natives relating to the preservation of human life and health.

Towards the end of the seventeenth century, the same causes which had so long before led to the cultivation of midwifery in China produced the same effect in Europe. The dangers to which women are sometimes exposed during labour excited the compassion of the benevolent; and hence a considerable part of the first hospital which was established for the reception of the indigent sick, the *Hôtel Dieu* of Paris, was appropriated to lying-in women. The opportunities of practice which that hospital afforded, directed the attention of medical men to the numerous accidents which happen during labour, and to the various diseases which occur after delivery. Public teaching followed, and soon afterwards began the custom of employing men in the practice of midwifery. From this period the art rapidly improved; and it is now in many parts of Europe, particularly in Great Britain, in as great a state of perfection as physic or surgery. There can be no doubt that the improvement of the art of midwifery chiefly arose from medical men directing their attention to the subject; but the propriety of men being employed in such a profession has been much questioned by many individuals of considerable respectability. It appears, indeed, that this question may be brought within a very narrow compass. It may be assumed as a fact established beyond the reach of controversy, that sometimes dangers and difficulties occur during labour, which can be lessened or removed by those only who have an intimate knowledge of the structure of the human body and of the practice of physic. On such occasions, it must be admitted, that medical men alone may be useful. But as such labours occur only in the proportion of two or three in the hundred, the general practice might be confided to midwives, if they could be taught to manage ordinary cases, and to foresee and distinguish difficulties or dangers, so as to procure in sufficient time additional assistance. It is on this point that the decision of the question must depend, and there can be no doubt that women may be taught all this. But there are many who allege, that, a little knowledge being a dangerous thing, midwives acquire a self-sufficiency which renders them averse to calling in superior assistance; and that, in consequence, they often occasion the most deplorable accidents both to the mother and the child. In England this is the popular opinion, and hence women are there almost entirely excluded from the practice of midwifery. A similar prejudice against midwives has, it is believed, begun in some parts of Scotland; but it is presumed this will gradually cease, when it is considered that, in general, the Scotch midwives are regularly instructed, and are at the same time both virtuous and industrious. If they attend strictly to their duty, and invariably prefer the safety of their patients to their own feelings or supposed interest, they will deservedly retain the public confidence. But if in cases of difficulty or danger they trust to their own exertions, or from interested motives decline the assistance of able practitioners, and if they interfere in the treatment of the diseases of women and children, they will in a few years be entirely excluded from practice. For details connected with the practice of midwifery, we refer to the professional works which treat of the subject, and which are too well known to require specification.

MIEZA, in *Ancient Geography*, a town of Macedonia,

Midwifery
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Mieza.

Mieza
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Milan. situated near Stagira, and in the olden time called *Strymonium*. Plutarch informs us, that in this place were shown the stone seats and shady walks of Aristotle.

MIGDOL, or MAGDOL, in *Ancient Geography*, a place in Lower Egypt, between Pihahiroth and the Red Sea. The term denotes a tower or fortress. It is probably the *Magdolum* of Herodotus; at least the Septuagint render it by the same name.

MIGRATION, the passage or removal of a thing out of one place into another. For the migration of birds, See ORNITHOLOGY.

MIGUEL, St, or ST MICHAEL, one of the Azore Islands, situated in long. 25. 45. W. lat. 38. 10. N. See AZORES.

MIHEL, a town of the department of the Meuse, and arrondissement of Bar-le-Duc, in France, on the right bank of the Meuse, containing 5250 inhabitants, who produce very good wine.

MIKHAILOW, a circle of the Russian province of Riasan, extending from east longitude 38. 24. to 39. 4. and from north latitude 53. 52. to 54. 29. It is very productive in corn, hemp, flax, and cattle. The capital is the city of the same name situated on the river Prona, and containing 408 houses and 2300 inhabitants. Long. 38. 42. E. Lat. 54. 12. N.

MILAN, called by the Italians Milano, and by the Germans Mailand or Mayland, is one of the governments into which the Austrian kingdom of Lombardy is divided. It was known as the duchy of Milan, till it came under the dominion of the imperial family of Austria. In the article ITALY of this work, the history of the ancient realm of the Longobards, with its kings of the iron crown, is noticed, as well as the other remarkable events respecting this country; and here we need only state the dates of the principal occurrences under the independent dukedoms.

The first duke was Galleazo Visconti, who was installed in that dignity by the Emperor Wenzel in the year 1395; and it continued in his family till the male line became extinct in 1447. France made some urgent efforts to obtain the authority, but these were of no avail, as Francisco Sforza, who had married an illegitimate daughter of the last Visconti, succeeded in gaining possession of the supreme power in this beautiful country, and transmitted it to his successors, who ruled till 1499. At that period Louis XII. king of France, and Francis I. emperor of Germany, laid claim to it. It was long the subject of contention between these two great powers, sometimes possessed by one, sometimes by the other, till after the decisive battle of Pavia in 1525, by which the emperor became master of Milan; and, by the treaty of Madrid in 1556, the possession of it was confirmed, when Francis granted it to Maximilian Sforza, to be held as a fief of the Holy Roman empire. The house of Sforza became extinct in 1535, upon which the Emperor Charles V. granted the duchy to his son Philip the Second, king of Spain. It remained under the power of the heirs of that crown till the war of the succession in 1706, when the events of that contest placed it in the hands of the house of Austria; but, by the treaty of Vienna in 1735, and by that of Worms in 1745, several portions of the country were delivered over to the king of Sardinia. The French revolution occasioned a successful invasion and much fighting, which in 1796 produced the ephemeral Cisalpine republic, which was annihilated by the Austrians and Russians in 1799; but the decisive battle of Marengo in 1801 gave the whole country to Bonaparte, who soon erected his kingdom of Italy, with the city of Milan as its capital and the residence of his viceroy. The peace of Paris in 1814 restored it again to the Austrian dominions, under which it has continued to the present day.

Milan is at present divided into the following nine delegations.

Delegations.	Extent in Square Miles.	Population.
Milan.....	1034	483,103
Brescia.....	1254	335,157
Cremona.....	484	182,559
Mantua.....	594	255,307
Bergamo.....	1452	205,042
Como.....	1450	356,015
Pavia.....	528	153,242
Lodi, with Crema...	748	204,042
Sondrio.....	1364	86,947
	8906	2,261,414

Milan.

By a late return, it appears that the males under seventeen years of age were 390,634, those between seventeen and twenty-four 88,993, those between twenty-four and thirty-four 105,780, those between thirty-four and forty-six 230,405, and those above forty-six were not classed, as the account was taken for military purposes, from which persons above that age are exempt.

The chief occupation of this body of inhabitants consists in the cultivation of the soil. As that subject has been discussed in what appears its most appropriate place in this work under the head of LOMBARDY, our readers are referred to that article. This government contains 462,700 families, who inhabit 279,160 houses, in fifteen cities, ninety-seven market-towns, and 3217 villages. It is bounded on the east by the government of Venice, on the north by the Swiss cantons, on the west by the territory of Sardinia, and on the south by Parma, Modena, and Sardinia. The northern part is mountainous and sterile, comprehending a portion of the Alps and extensive lakes; but the southern and much the larger part is level and highly fertile, being watered by numerous streams issuing from the lakes, all of which, with their various tributary rivulets, are finally emptied into the Po. There are abundance of canals connected with the rivers and with each other, which are made use of both for the purposes of irrigation and for the conveyance of goods; but on these highly interesting topics we must refer the reader, as before, to the general article LOMBARDY.

MILAN, a city, the capital of the Austrian kingdom of Lombardy, as well as of the delegation in which it stands. Although it has suffered much by war, and by the political events of the last fifty years, it is still the richest, and, except Naples, the most populous city of Italy. It stands on the river Olona, and, by means of the canal called *Naviglio Grande*, is connected with the river Ticino, and, by the Martesana, with the river Adda. From this water intercourse, and from the excellence of the roads in all directions round the city, the markets are supplied with every necessary in the most convenient and easy manner.

The city is nearly of a circular figure; it is walled, but scarcely defensible against a decided attack; and it is protected by a citadel containing six bastions. The whole compass of the wall is 5900 fathoms, or nearly seven English miles. The longest part, from the *Porta Romana* to the *Porta Sempione*, is 1800 fathoms; and the broadest part, from the *Porta Ticinese* to the *Porta Orientale*, is 1600 fathoms. The wall is furnished with eleven gates, some of which are the most striking objects of the city, and merit special notice. The most remarkable of these is that at the gate leading to Ticino, which resembles the entrance to a Roman temple. It is built of granite, and consists of colossal pillars of the Ionic order, with an appropriate peristyle; and in connection with it is the fine bridge over the Naviglio Grande. The *Arco della Pace*, or *del Sempione*, Bonaparte had formed the design of erecting as a trium-

Milan.

phal arch to celebrate his conquest and dominion over Italy. It was not finished at the fall of Napoleon in 1813, but was completed by the Emperor of Austria in 1816, and a name given to it intended to commemorate the return of peace. The pillars, of six feet in circumference and forty feet in height, formed out of a single block of marble, are its most distinguishing ornaments. The arch resting on them, of a breadth nearly equal to that of Constantine, is ornamented with a car of bronze, to which six horses are harnessed, and in which the goddess of victory is seated. The whole building is of white marble, with the various figures and bas-reliefs of bronze.

The streets of this city are generally narrow and crooked, and rather gloomy from the height of the buildings. One of the streets, the Corso, or High Street, is an exception; it runs through the whole city, is nearly two miles and a half in length, is of great breadth, and on both sides has magnificent and lofty houses. In the whole city the pavement is far better than is usually seen in towns on the Continent. It is composed of small pieces of marble or of granite, and in the middle, where the carriages pass, there are in the narrow streets two, and in the broad streets four, rows of flat granite laid down, on which the wheels run; and for foot passengers there is a similar pavement close to the houses. The streets are kept clean, which is owing to a branch of industry exercised by the poorest people, who collect in baskets whatever filth can be converted into manure, and carry it out of the gates, where it always finds ready purchasers.

There are in Milan few piazzas or squares, and none either large, fine, or even regular. The Piazza di Duomo is long, but narrow and disfigured by the booth-like shops and buildings that surround it. The Piazza di Mercante has in its centre a portico where the traders assemble, but it is small. The Piazza Fontana has a fine fountain, with two excellent figures in marble. The Piazza d'Armi, formerly the Foro Bonaparte, is the best promenade in Milan. It is used as an exercising place for the garrison, stands near the citadel, and on Sundays and holidays is much frequented by the more fashionable part of the inhabitants. It is planted with trees, and is about 600 yards long and 540 broad.

Amongst the public buildings in Milan, the churches are the most remarkable; the first of which, the *Duomo* or cathedral, is the most remarkable. Next to St Peter's at Rome, it is the largest church in Italy. It is 480 feet in length, 285 feet in breadth; the height of the cupola is 240 feet, and of the highest pinnacle 352 feet. This vast edifice, dedicated to St Charles, was commenced so long ago as the year 1386. The various turns of fate that have attended the city have had their influence in retarding or furthering the progress of the work. Under Napoleon, large sums were drawn from the public revenue and applied to this structure; and since the restoration of the Austrian government, the Emperor of Austria has directed 12,000 francs, or about L.500, to be paid monthly till the completion of the edifice. It is now finished, except the placing of a number of statues, for which vacant places are left, and some few ornaments which wait the finishing touch of the artists. The outside of the church, which is wholly of white marble, and which in several places, from the weather, had become black, has been well rubbed, and now appears quite as white as the newer parts.

It is to be regretted that there is no place from which a good point of view of this cathedral can be obtained. On three sides it is built up by narrow streets, and only the majestic front with its five colossal entrances can be seen from the Piazza di Duomo.

The whole building is in the Gothic style, but it has been frequently departed from, which is considered by the critics as its greatest, or, indeed, its only fault. A vast col-

Milan.

lection of figures from the hands of the most eminent statuary, to the number of more than 5000, are placed upon the walls, upon the Gothic turrets, and upon the pinnacles. They are images of various saints, all as large as life. Richly-ornamented galleries, with finely-carved volutes and roses, extend from one tower to the other. The roof is a surprising work, which is reached by a winding staircase of two hundred steps, from which the labyrinth of pillars surrounding the spectator has a most singular effect. In the centre of the roof rises the majestic dome, on which is placed a bronze statue of the Virgin Mary.

The church has five entrances, which lead to that number of divisions, pointed out by fifty-two octagonal marble pillars, eighty-six feet in height, which are bound together at the top by Gothic arches. The altars are numerous and richly ornamented, and on the floor a meridian line was inserted in 1786. The floor is composed of pieces of marble of different colours, by which various ornamental figures are formed. The first entrance to this edifice is most imposing and exciting. The panorama from the top is very gratifying, exhibiting near to it the whole circuit of the city; the verdant fields in contact with it on the south side; the rich plain of Lombardy, extending to the river Po, and terminating with the Apennines, studded with towns, villages, and hamlets, intermingled with vineyards and woods of mulberry trees; whilst on the north the same kind of prospect is bounded by the Alps, having Monte Rosa in front, with ranges of mountains rising one above the other, the most distant rearing their tops into the region of eternal snow. The other ecclesiastical edifices are numerous, being stated to be no less than seventy-nine, most of them of great interest; but our space will admit of noticing but a few of the most remarkable. The imperial collegiate church of St Ambrosio is distinguished by its antiquity; and the most costly ornaments, and numerous objects of art, are to be seen within it. It is a kind of museum for the history of the arts, and is also the church in which the kings of Lombardy of the iron crown were consecrated. The church of St Alessandro contains valuable treasures in paintings chiefly in *fresco*, and sumptuous statuary; whilst the capitals of the pillars that support it are of bronze. The church of St Nazaro is one of the finest and largest in the city, and is adorned with some of those best paintings, both in oil and in *fresco*, which have immortalised the masters of the Italian school. St Sebastian's is worthy of notice from its architecture in the rotunda form. It was formerly a Roman temple, and still displays many specimens of its antiquity. It is said to have been one of the three churches which Barbarossa spared from his general devastation. The church of St Fidele unites simplicity with great extent, but its façade is yet unfinished. The St Maria Maggiore contains many very fine ancient paintings, and the monument of St Bernhardin. The celebrated *fresco* painting of the Last Supper, by Leonardo da Vinci, remains in what was formerly the refectory of the Dominican convent, but is now used as a magazine for hay and straw. It has been much neglected, and the saltpetre, which has extended itself over the wall on which it is painted, has destroyed the glow of the colours, and in many places the paint has peeled off, whilst in others it is covered with mould. Several amongst the civil buildings are deserving of notice. The royal palace, though its exterior makes but little impression, is the residence of the viceroy. It is called the Villa, and contains a magnificent apartment, in which stands the throne. It contains many curiosities, and amongst the rest the *fresco* paintings of Appiani. The palace of the archbishop is a fine piece of architecture, and contains an admirable collection of paintings. The Palace Marini, now used as an office for the public accounts, is considered as the most perfect, as it is one of the largest, buildings in Milan. Besides these edifices, the mint, in which

Milan. is a fine statue of Philip II. of Spain, the Villa Belgioso, the palaces of the families of Serbelloni, of Cicogna, of Litta, of Melzi, of Andreani, of Borromeo, and of numerous others, are of great extent, as well as of various kinds of architecture, and produce much interest amid the general aspect of the city.

Of modern buildings, the barracks, erected under the viceroyship of Eugene Beauharnois, are the largest, the most handsome, and the most convenient, of any pile of the kind in Europe.

The establishments and the erections devoted to the sciences, to literature, and to the fine arts, are the most distinguishing objects on which the Milanese can pride themselves. Above all others is the Brera, formerly the college of the Jesuits, and before them of a brotherhood called *Umiliati*; at present it is connected with the university of Pavia. The interior square of the building is surrounded with colonnades, on the ground floor composed of Doric, and on the upper floor with Ionic pillars, forming open halls. The tower of this edifice is employed as an astronomical observatory, and the garden is made use of for the purpose of botany. The ground floor is adapted for lecture-rooms, and the upper floor contains a library of more than 100,000 volumes and numerous valuable manuscripts. Adjoining to it is the picture-gallery, containing many excellent productions, especially some most valuable fresco paintings, which have been preserved and removed from the churches and monasteries in and around the city. On the upper story are apartments, wherein is a collection of numerous casts of ancient and modern sculpture in plaster of Paris, and also one of coins and medals.

The next in celebrity of the libraries in Milan is the Ambrosian, founded by Cardinal Borromeo. It consists of 60,000 volumes of books, and 15,000 of manuscripts, now bound so as to form only 6000 volumes. With this, in some other apartments, are connected collections of pictures and of statuary, both of great merit. Besides these public establishments, there are many collections of old and valuable works in the libraries Fagnani, Melzi, Reina, Litta, Archinto, and Trivulzi.

In this large city, where the destitute, the aged, and the infirm, are very numerous, the institutions for their relief are upon a commensurate scale. The *Ospitale Maggiore* is a prodigious range of building, with a beautiful front, entered by magnificent portals of 450 feet in length. The usual number of patients contained in it is from 3700 to 4000. With this is connected the foundling hospital, in which 1100 children are maintained within the walls, and about 2900 are sent to board in the villages around the city. There is also a large lying-in-hospital; a lunatic asylum, in which are kept generally 420 insane persons; the lazaretto, containing many small houses without the gates, as a precaution against the plague; the Trivulzi, which contains 480 poor of both sexes, above seventy years of age, who are maintained by property bequeathed to it by the noble family of that name; an orphan-house, which supports 350 young persons, and several smaller institutions. Besides these, the monks and the nuns of the order of mercy have each their benevolent establishments.

The places of amusement are not numerous, though upon a large scale. The opera-house, *Della Scala*, is one of the most extensive theatres of Europe. It was built in 1776, on the site of an ancient church of that name. It contains 240 boxes in six tiers, one above the other, and has seats for 800 persons in the pit, besides standing room in the centre and both sides of it, so that it is calculated to contain 7000 spectators. The performers, both in music and dancing, are of the very first class during the fashionable season. There is also another, the imperial theatre, or *Canobbiana*, and four or five small private theatres.

The city, including the suburbs and the garrison, contains

145,000 inhabitants. The chief wholesale trade consists in silk, either raw or spun, and in cheese; for the particulars of which see the article *LOMBARDY* in this work. The retail trade is much divided, and consists in that usually carried on in large cities, which it dispenses to the towns and the villages around it for domestic use. As Milan is a kind of metropolis to the north of Italy, and resorted to in the winter by the rich, at that time of the year the tradesmen are in full occupation; but at other seasons they have little occupation, except what arises from the foreign visitors.

The city, by observation taken at the cathedral, is in long. 9. 5. 45. E. and lat. 45. 27. 35. N.

MILAZZO, a parliamentary city of the island of Sicily, in the kingdom of Naples, on the sea-shore, near the termination of Cape Blanco. It is fortified, and though the situation is rather unhealthy, it contains a population of 8000 persons, who are chiefly occupied in the tunny fishery, and in the export of wine and oil.

MILBOURN-PORT, a town of the county of Somerset, in the hundred of Horethorne, 117 miles from London. It stands on a branch of the river Parret, and is a poor and scattered place, with small houses, chiefly built for election purposes. It formerly returned two members to the House of Commons, but has been disfranchised. It has no market. The population amounted in 1801 to 953, in 1811 to 1000, in 1821 to 1440, and in 1831 to 2072.

MILDENHALL, a town of the county of Suffolk, in the hundred of Lachford, seventy-one miles from London. It is situated on a branch of the river Ouse, which is navigable for barges up to it, and is a source of its trade. There is a well-supplied market, which is held on Friday. The population amounted in 1801 to 2283, in 1811 to 2493, in 1821 to 2974, and in 1831 to 3267.

MILDEW is said to be a kind of thick, clammy, sweet juice, exhaled from, or falling upon, the leaves and blossoms of plants. By its thickness and clamminess it prevents perspiration, and hinders the growth of the plant. It sometimes rests upon the leaves of trees in the form of a fatty juice, and sometimes upon the ears of corn. It is naturally tough and viscous, and becomes still more so by the sun's heat exhaling its more fluid parts; by which means the young ears of corn are so daubed over that they never arrive at their full growth. Bearded wheat is less subject to the mildew than the common sort; and it is observed that newly-manured lands are more liable to mildew than others. The best remedy is a smart shower of rain, and immediately afterwards a brisk wind. If the mildew be observed before the sun has attained power, it has been recommended to send two men into the field with a long cord, each holding one end; and drawing this along the field over the ears, the dew will be dislodged from them before the heat of the sun has been able to dry it to the viscous state in which it does the mischief, or rather, perhaps, to occasion that rapid evaporation which produces a degree of cold sufficient to nip and chill the ears, or, in other words, to affect them with mildew. Some are of opinion that lands which have for many years been subject to mildews have been cured of it by sowing soot along with the corn, or immediately after it is sown.

MILE, a measure of length or distance, containing eight furlongs. The English statute mile is eighty chains, or 1760 yards, or 5280 feet. See *WEIGHTS AND MEASURES*.

MILETO, a city, the Miletus of antiquity, of the kingdom of Naples, in the province of Calabria Ulteriore. It stands on elevated ground, but is watered by three small streams. It is the seat of a bishop. By the earthquake in 1783, the castle, the cathedral, a parish church, two monasteries, and many dwellings, were thrown down, and 1700 lives were lost. It has been in some degree rebuilt since.

Milazzo

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Mileto.

Miletus
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Milillo.

MILETUS, in *Ancient Geography*, a town of Crete, mentioned by Homer, but the situation of which has not been ascertained. It is said to have been the mother town of Miletus in Caria, whither a colony was led by Sarpedon, brother of Minos.

MILETUS, in *Ancient Geography*, a celebrated town of Asia Minor, situated on the confines of Ionia and Caria. It was the capital city of Ionia, famous both for the arts of war and peace, and situated about ten stadia south of the mouth of the river Mæander, near to the sea coast. It was founded by a Cretan colony under Miletus the companion of Bacchus, or by Neleus the son of Codrus, or by Sarpedon a son of Jupiter. It has been successively called *Lelegeis*, *Pithyusa*, and *Anactoria*. The inhabitants, called *Milesii*, were very powerful, and long maintained an obstinate war against the kings of Lydia. They early applied themselves to navigation, and planted no less than eighty colonies, or, according to Seneca, three hundred and eighty, in different parts of the world. This was the only town which made head against Alexander, and which was with much difficulty taken. It gave birth to Thales, one of the seven wise men, and the first who applied himself to the study of physical science. It was also the country of Anaximander, the scholar and successor of Thales, the inventor of the gnomon, and the first who published a geographical map; of Anaximenes, the scholar and successor of Anaximander; and also of other illustrious men. It was noted for its excellent wool, and was also celebrated for a temple and oracle of Apollo Didymæus. It is called by the Turks *Melas*, and not far distant from it flows the river Mæander. St Paul proceeding from Corinth to Jerusalem passed by Miletus, and as he went by sea, and could not take Ephesus in his way, he caused the bishops and priests of the church of Ephesus to come to Miletus, which was about twelve leagues distant.

MILFORD, a town of North America, in Sussex county, in the Delaware state, is situated at the source of a small river, fifteen miles from Delaware Bay, and 150 southward of Philadelphia. This town, which contains about eighty houses, has been built, excepting one house, since the revolution. It is laid out with much taste, and is by no means disagreeable. The inhabitants are Episcopalians, Quakers, and Methodists.

MILFORD HAVEN, a township of Pembrokeshire, in South Wales, in the parish of Harbrandstone, 257 miles from London. The town is of recent origin, having been created by the excellence of the haven, or rather bay, which, both in regard to extent and security, is perhaps one of the best in the south of the island. It has several creeks and bays, is calculated to receive a thousand sail of vessels, and is well fortified. It was the first place which commenced the southern whale-fishery; and many ships of war have been built there, as well as smaller vessels. It is the principal point of communication between the south of England and of Ireland, by vessels daily departing for Waterford. The nearest town to the Haven is Habers-ton.

MILHAU, an arrondissement of the department of Aveyron, in France, 775 miles in extent. It consists of nine cantons, divided into thirty-nine communes, and contains 65,800 inhabitants. The capital is the city of the same name situated on the right bank of the Tarn, where the Dourbie falls into that stream. The surrounding country abounds with fruit, especially almonds and grapes. In the year 1836 it contained 10,450 inhabitants, who make gloves, hats, various kinds of leather, and some porcelain. Long. 17. 1. E. Lat. 44. 10. N.

MILILLO, a city of the island of Sicily, in the kingdom of Naples, and province of Noto, 140 miles from Palermo. It stands on a mountain near the river Cantara, and is a healthy place, with 4000 inhabitants.

MILITARY, something belonging to or connected with the profession of a soldier.

MILITARY DISCIPLINE, the training of soldiers, and the due enforcement of the laws and regulations instituted by authority for securing obedience and repressing all disorderly habits or tendencies. Next to the forming of troops, military discipline is an object of the first importance. It is the soul of all armies; and, unless it be established with great prudence, supported with unshaken resolution, and enforced with rigour tempered by judgment, an army is no better than an armed mob, and is more formidable to the state that maintains it than dangerous to its declared enemies.

MILITARY EXECUTION, the ravaging or destroying of a country or town which refuses to pay the contributions imposed upon them, or which has incurred that penalty from any transgression of the usages of war.

MILITARY STATE, in British polity, is one of the three divisions of the laity. This state includes the whole of the soldiery, or such persons as are peculiarly appointed for the safeguard and defence of the realm.

In the time of the Anglo-Saxons, the military force of England was in the hands of the dukes or heretochs, who were constituted throughout every province and county in the kingdom, being taken from the principal nobility, and such as were most remarkable for being *sapientes, fideles, et animosi*. Their duty was to conduct and regulate the English armies with unlimited power, *prout eis visum fuerit, ad honorem coronæ et ad utilitatem regni*. And because of this great power, they were elected by the people in full assembly, that is, by folk-mote, in the same manner as sheriffs were elected; according to the fundamental maxim of the Saxon constitution, that where any officer was to be intrusted with such power as, if abused, might tend to the oppression of the people, that power should be delegated to him by the vote of the people themselves. The ancient Germans, the ancestors of our Saxon forefathers, had also their dukes, as well as kings; with an independent power over the military, as the kings had over the civil state. The dukes were elective, the kings hereditary; *reges ex nobilitate, duces ex virtute sumunt*. In constituting their kings, the family or blood royal was regarded; in choosing their dukes or leaders, they had respect to warlike merit alone. Cæsar relates of their ancestors in his time, that whenever they went to war, either offensively or defensively, they elected leaders to command them. This large share of power, thus conferred by the people, though intended to preserve the liberty of the subject, was perhaps unreasonably detrimental to the prerogative of the crown. Accordingly we find that, in the reign of King Edmund Ironside, a very bad use was made of it by Edric, duke of Mercia, who, by his office of duke or heretoch, was entitled to a large command in the king's army, and by his repeated treachery at last transferred the crown to Canute the Dane.

It seems to be universally agreed by all historians, that Alfred first settled a national militia in this kingdom, and by his prudent discipline made all the subjects of his dominions soldiers. But we are unfortunately left in the dark as to the particulars of this celebrated regulation; although, from what has been observed, the dukes seem to have been left in possession of a power so large and independent that, on the death of Edward the Confessor, it enabled Duke Harold, though a stranger to the blood royal, to ascend the throne of this kingdom, in prejudice of Edgar Etheling, the rightful heir.

Upon the Norman conquest, the feudal law, in all its rigour, was introduced into this country, the whole of that system being built on a military plan. Hence all the lands in the kingdom were divided into what were called *knights' fees*, in number above sixty thousand; and for every knight's fee, a knight or soldier, *miles*, was bound

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to attend the king in his wars for forty days annually ; in which time, before war was reduced to a science, the campaign was generally finished, and a kingdom either conquered or victorious. By this means the king had, without any expense, an army of sixty thousand men always ready at his command. Accordingly we find one amongst the laws of William the Conqueror, which commands and enjoins the personal attendance of all knights and others, *quod habeant et teneant se semper in armis et equis, ut decet et oportet ; et quod semper sint prompti et parati ad servitium suum integrum nobis explendum et peragendum, cum opus adfuerit, secundum quod debent de feodis et tenementis suis de jure nobis facere.* This personal service in process of time degenerated into pecuniary commutations or aids ; and at last the military part of the feudal system was at the Restoration abolished, by statute 12 Car. II. c. 24.

MILITARY or MARTIAL LAW, is that branch of the laws of war which respects military discipline, or the government and control of persons employed in the operations or for the purposes of war. Military law is not exclusive of the common law ; for a man, by becoming a soldier, does not cease to be a citizen or a member of the commonwealth. He is a citizen still, capable of performing the duties of a subject, and answerable in the ordinary course of law for his conduct in that capacity. Martial law is, therefore, a system of rule superadded to the common law, for regulating the citizen in his additional character of soldier ; a temporary character assumed for a special end, and to be laid aside when that end has been attained, and when the disturbance which gave occasion to it has subsided. For, as the law knows nothing of a mere soldier, or one bred up to no other profession than that of arms, so a perpetual standing army is against the principles of the constitution, and, if without consent of parliament, is clearly against law.

Throughout all Europe, in the feudal times, property was commonly held upon condition of military service ; and the possessors of land were, by virtue of their right, at once its cultivators in peace and its defenders in war. But the fetters of land under the feudal system were incompatible with a state of commerce, and the arbitrary power of lords over their vassals was adverse to civil liberty ; its strictness declined ; the services of tenants were commuted for money, and with money were purchased the services of mercenaries, who were ready to make war a trade. The disorders incident to the disbanding of these troops, the changes which had taken place in the mode of warfare, and the necessity of attending to the balance of power in Europe, all concurred to suggest the idea of a disciplined standing army, which was formed first in France, and then in the other states of Europe. The military despotism, however, which ensued on the Continent was in this country happily prevented by the spirit of a free people ; and at the Revolution it was asserted and declared, that the raising or keeping up a standing army within the kingdom, in time of peace, without consent of parliament, is contrary to law. The expediency of a standing army is admitted, and at the same time the liberties of the people are maintained. A standing army therefore exists, but primarily for the benefit, because only with the consent, of the people.

In early times the king's justiciar was *caput legis et militiae* ; at the head not only of the law, but also of the military force of the kingdom. But in England, on the division of the *aula regis*, the constable and marischal presided over a court of chivalry for the determination of matters of honour and arms. From time to time, however, other tribunals were subsequently instituted for the administration of martial law ; and at length, after the Revolution, when, in addition to the militia and other local troops of the kingdom, a regular standing army was judged ne-

cessary for the safety of the realm, the defence of the possessions of the crown, and the preservation of the balance of power in Europe, acts were passed for the maintenance of military order and discipline. Scotland differed from England in this respect, that there was here no distribution of the powers of the lord justiciar, such as took place in England, nor was there ever any court of chivalry. In other respects the two countries were, in as far as concerns martial law, very much alike.

The first of the military acts which passed after the Revolution was occasioned by a mutiny in a body of English and Scotch troops (amongst whom were the regiment of dragoons now called the Scotch Greys, and the royal Scotch regiment of foot), on being ordered to Holland to replace some of the troops of that country which King William had brought over with him. The circumstance was communicated to parliament, and on the 3d April 1689 an act was passed for punishing mutiny, desertion, &c. It authorized the king to grant commissions to certain officers to hold courts martial, for the trial of crimes committed by officers and soldiers ; and this act, which has been renewed from time to time, has since the Union been extended to Scotland.

An act of the same nature was passed in the parliament of England, 13 Cha. II. stat. i. c. 9, authorizing the lord high admiral to grant commission to inferior vice-admirals, &c. to assemble courts-martial for the trial of offences committed at sea by officers, marines, or others in the king's naval service. But this statute was in many points altered by subsequent enactments, till at last all the laws relating to courts-martial for the sea service were reduced into one act, applying equally to the whole united kingdom, namely, 22 Geo. II. c. 33, explained and amended by 19 Geo. III. c. 17.

The more recent statutes for the government of the forces, naval and military, are 1 Will. IV. c. 14, 15 ; 2 and 3 Will. IV. c. 23, 28 ; 3 and 4 Will. IV. c. 5, 6 ; 4 and 5 Will. IV. c. 4, 5, &c. To detail the provisions of these acts would extend this article beyond the limits allowed to it ; and it is not necessary to do so, as the acts themselves, which are very full and explicit, must be in the possession of those interested in them. We shall only observe, that the judgments of courts-martial, like those of other courts, are liable to be taken cognizance of in the superior courts of common law, and the members punished for illegal proceedings, and for all wilful and corrupt abuse of authority against the known, obvious, and common principles of justice.

(See Tytler on *Courts-Martial* ; Adye on *Courts-Martial* ; and M^rArthur on *Courts-Martial*.) U. U. U.

MILITARY Tenures. See FEODAL SYSTEM, and KNIGHT.

MILITELLO, a city of the island of Sicily, in the kingdom of Naples and province of Noto, 120 miles from Palermo. It is moderately healthy, being situated on a rocky mountain, and contains 8000 inhabitants. Near to it are some valuable salt lagunes.

MILITIA, from the Latin *miles*, a soldier, in its original signification, means warfare, the qualification of soldier-ship, or the military body. In this last signification it became incorporated with the English language. It is now used to distinguish, from the regular forces, the body of citizens who may be annually called out for a limited time, and embodied on occasions of emergency. As the system out of which the present militia has arisen existed previously to the establishment of a mercenary army, and frequently constituted the sole military organization of its time, a historical sketch of the institution will involve to a certain extent a general view of the military state of Britain during the earlier periods of our history.

Any account of the military system of the Saxons, especially when we approach the era of the Norman conquest,

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Militia.

Militia.

becomes involved in the great question as to the extent to which feudal practices had been adopted in England previous to that event. It has, however, been distinctly ascertained, that land, amongst the Anglo-Saxons, became not only the reward of military services performed, but the stipulated wages of their continuation. Thus there came to be a connection between the performance of services to a chief and the holding land under him, the soldier or thane possessing the land on the condition of performing military duties, but not, as by the mature usages of the feudal system, rendering the service as an incident of the tenure of the land. The grants so made were generally for a contingent period, and were revocable from a vassal unfit to perform his military engagements; and we find amongst them a species of transaction so complicated as grants to churchmen, on the condition of their making provision for the performance of the military duties they were personally disqualified from undertaking.¹ The oath of the vassal was personal and conditional, and had no reference to the land as a bond of union.² It was the duty of the superior to protect his follower, and when he ceased to do so, the vassal was relieved from obedience; but desertion was viewed as a crime of great magnitude. Those freemen who had not undertaken to perform military service in return for lands were entitled, like the clients of the Romans, to select their own "Hlafords" or patrons; but this class of followers seems to have gradually decreased towards the era of the conquest, when it would appear from Domesday-book that all land was, or was presumed to be, held of a superior. It was perhaps for the furtherance of such a principle, without the invasion of existing free rights in property, that an exception sometimes appears in favour of the tenant: "Et poterat ire cum ea (terra) ad quem vellet Dominum;" intimating that he might hold his land of whatsoever lord he chose.

Whatever right the patron may have had to the exclusive military services of his dependent, it undoubtedly yielded to the claim of the state to the assistance of every freeman in cases of invasion or rebellion. It is probable that when the national force, denominated the *Fyrd*, was brought into existence, the right of patronage gave the superior no further power than that of leading his dependents when they joined the general host. The approach to any decision on this point is impeded by many difficulties, arising from the incongruities in the practice of different periods and of different parts of the country, and the absence of any contemporary treatise explanatory of the general rules and the reason of the apparent exceptions. It is thus that on some occasions the right of the Hlaford to command his followers is spoken of without any reference to the paramount claims of the public, whilst elsewhere we find the community arrayed by command of the sovereign, without reference to the circumstance that two distinct classes are to appear in the field, in the respective position of patrons and vassals. "From the earliest period," says Sir Francis Palgrave, "to which our documents can reach, we find the *Fyrd* appearing as a general armament of the people, comprehending every rank, though under different obligations and penalties. If the *Sithcund-man*, being a landholder, remained at home, he forfeited all his land; sixty shillings was his fine; whilst thirty shillings was the *Fyrdwite* of the churl, and to the last it continued a levy of all the population of the country."³ Sir William Blackstone and others include the national militia amongst the improvements attributed to the inventive genius of the great Alfred. The *Fyrd*, however, is of earlier origin. In

the laws attributed to Edward the Confessor, the authenticity of which is justly doubted, though they are certainly the work of some one well acquainted with the Anglo-Saxon constitution, there are regulations for the organization and discipline of the *Fyrd*, probably embodying those improvements of Alfred which procured him the credit of having planned the system. These regulations adapt the arms to be provided by each freeman to a scale of wealth; forbid their being sold or pledged under penalties; provide for their descending to heirs; and appoint annual exhibitions, which, in order to baffle attempts to display the same weapons in different districts, were to take place simultaneously all over the country.⁴ The command was given to district-leaders called "Heretochs," who, it is stated, were, like the *vice-comites* or sheriffs, elected by their respective districts in full folk-mote. Sir William Blackstone observes, that the power thus vested in the people proved dangerous to the community, by erecting a rival to the royal prerogative; and he refers to this source of influence the treachery of Eric Streone, and the usurpation of Harold. Whatever the theory of the Anglo-Saxon constitution may have admitted, however, it does not appear, from the history of the period, that the voice of the people regularly influenced the command of the natural force; and undoubtedly, in the instances cited, the power unduly used had been otherwise obtained.

The Norman conquest did not produce so much effect, by altering the system so established, as by bringing the new engine of feudalism to act in concert with it. The king was then the commander of two separate forces. His feudal army was furnished by the tenants of his knights' fees, for each of which he could demand the service of one knight or of two esquires for forty days. These were his personal followers during their period of service, and were liable to be employed either at home or abroad. But the absolute demand on his services was inconvenient to the vassal, and the limitation of the period was often no less so to the king. Hence those who were partial to the occupation of war frequently remained with the army beyond their assigned period for a stipulated remuneration, whilst others got their services commuted into a money-payment, which afterwards merged into the oppressive exaction of scutage. Whilst this new species of force came into operation, the *Fyrd* of the Saxons still remained in existence. It afterwards was the source whence arose two distinct institutions; the *posse comitatus*, liable to be called out by the sheriff to keep the king's peace; and the militia force of the present day.

In the celebrated "assize of arms" of 1181, we find the *Fyrd* of the Anglo-Saxons in its original purity. All freemen are appointed to have arms in their possession, according to a scale of ranks, which consists, first, of the holders of a knight's fee; secondly, of the possessors of chattels or rents to the extent of sixteen merks; thirdly, of the holders of similar property to the value of ten merks; and, lastly, of all other burgesses and freemen.⁵ The *Fyrd*, with its periodical exhibitions of arms, was recognised as late as the year 1285, when, by the statute of Winchester (13 Ed. I. st. 2, c. 6), the scale of arms assigned to the respective ranks was revised. The part of the act which enforces the keeping of arms was adjusted to the progress of the art of war in 1558 (4 and 5 Ph. and M. c. 2), and finally abolished in 1604 (1 Jac. I. c. 25, sect. 46).

Meanwhile practices commenced which gave rise to much subsequent dispute respecting the question, how far the right of the monarch to demand the military assistance of

Militia.

¹ Sir Francis Palgrave's *Rise and Progress of the English Commonwealth*; *Proofs and Illustrations*, ccxx.

² Allen on the *Rise and Growth of the Royal Prerogative*, Ap. xxii.

³ *Proofs and Illustrations*, *ut supra*, ccclxviii.

⁴ *Leges Edwardi*, apud Wilkins, sect. 35.

⁵ Wilkins, 296.

Militia. his subjects in such wars as he chose to prosecute, was restricted. Many apparent anomalies in the constitution of this early period may be explained by reflecting that the Anglo-Saxon people continued to cherish certain privileges and customs which the Norman monarchs were often unable openly to abolish, whilst they were frequently powerful enough to infringe them. The annual array was an institution with which they naturally tampered, finding it their interest to amalgamate it with their feudal prerogatives. On the other hand, there were no definite limits to the prerogative, which insinuated itself wherever it was not practically checked. Accordingly we find parliament avoiding for some time any distinct recognition of the prerogative of the crown, or the privileges of the subject, and acting on the defensive against the former. Thus, by statute 1 Ed. III. c. 5, "The king wills, that no man from henceforth shall be charged to arm himself, otherwise than he was wont in the times of his progenitors kings of England; and that no man be compelled to go out of his shire but where necessity requireth, and sudden coming of strange enemies into the realm; and that it shall be done as hath been used in times past for the defence of the realm." The seventh chapter of the same statute gives redress on complaints that commissioners appointed to raise soldiers had been chargeable to the shires; and by the instructions to the sheriffs in the 10th Ed. III. stat. ii. money so exacted is directed to be returned. More decided attempts to amalgamate the assize of arms with the feudal force appear to have been opposed in 1351, when by 25 Ed. III. stat. v. c. 8, it was enacted that "no man shall be constrained to find men of arms, hobelers nor archers, other than those who shall hold by such services, if it be not by common assent and grant made in parliament."

At an early period, the crown gradually enlarged its military authority, by issuing commissions of array. These writs, which were at first probably mere authorities to individuals to use the royal name and influence in collecting troops, came from practice to be viewed as emanating from the prerogative. In that anxiety to avoid collision with the crown, which distinguishes many of the old acts of parliament, they are frequently alluded to without being either sanctioned or condemned. A singular instance of apparently intentional ambiguity occurs in 1 Ed. III. stat. ii. c. 15, which was avowedly passed for the relief of individuals, who, at the suggestion of "false and evil counselors," had been prevailed on by "duress" to come under burdensome obligations to perform military duties. The contracts are cancelled with a sort of oracular qualification, evidently inserted as the nominal price of a real concession: "Considering that such writings were made to the king's dishonour, sithens that every man is bound to do to the king as his liege lord all that pertaineth to him, without any manner of writing." In the fifth year of Henry IV. a statute was passed limiting the form and authority of commissions of array. It involves the anticipation of foreign invasion, empowers the commissioners in such circumstances to array and train all men-at-arms, to cause all able-bodied men to arm themselves according to their substance, to amerce those unable to bear arms in a similarly adjusted ratio, and to require the services of persons so armed on the sea-shore, or elsewhere, at the moment of danger. It is singular that this statute, which forms the only legislative authority to which Charles I. finally appealed in the celebrated struggle for the command of the militia, has never been conceived of sufficient importance to be printed in any collection of the statutes, and seems to have been accidentally discovered in manuscript by some of the crown officers.¹ It was indeed,

like the last cited statute, an act of grace, having been passed for the protection of the persons nominated as commissioners, who, according to the preamble, were liable to many penalties and forfeitures in the performance of their assigned duties. It is worthy of note, as bearing on the extent of the authority intended to be conferred by this act, that during the previous year (by 4 Hen. IV. c. 13) the enactments above referred to, checking the encroachments of the royal authority, were all jealously confirmed; the holders of lands in Wales and of military fiefs, and persons who had bound themselves by contract to perform military services, being specially excepted. During the Tudor dynasty, the declaratory limitations attempted by the old statutes were undoubtedly little respected by the crown, and forced levies were made on many occasions, when the necessities contemplated by the acts could be brought forward as a nominal justification, without being minutely questioned. A statute of the year 1558 (4 and 5 Phil. and M. c. 3) appears at first sight to give full sanction to the right of impressment; but an observation of the circumstances in which the act was to be enforced, and reference to a previous act which it professed to amend, show that it was intended for the discipline of those who had become soldiers, and to prevent their desertion. During the long parliament, by an act granting the temporary power of impressing as many men as the king and both houses of parliament might appoint (16 Car. I. c. 28), the limitations were again confirmed; and it was declared, that by the law of the realm the subject ought not to be impressed or compelled to go beyond his county, &c. in the same terms as the statute of the first of Edward III.

Such was the state of matters when, in the celebrated dispute between Charles I. and the parliament regarding the right to command the militia, it was maintained on the one hand that the preservation of the peace of the country, and its protection from foreign invaders, were the unalienable privileges of the crown, and involved the right to command all armies, and to demand on all occasions the military service of the lieges; and, on the other, that such privileges existed in no individual without the consent of both houses of parliament; whilst it was urged, first in the form of an ordinance, and next in that of a bill, that the king should consent to the militia being placed in the hands of commissioners named by parliament. Although the statutes above referred to show that in moments of danger the king was so far the guardian of the peace, that he was entitled to put himself at the head of the persons bound to keep themselves in readiness for such occasions, and the practice had been undoubtedly still more favourable to the prerogative, neither an act of the legislature, nor any uninterrupted train of precedents, had given the monarch the unlimited military command which he arrogated. At an unfortunate time for the adjustment of such a question, it had to be settled between the conflicting branches of the legislature; and Whitelocke at least approached the truth, when he said he apprehended "that the power of the militia is neither in the king only, nor in the parliament; and if the law hath placed it any where, it is both in the king and parliament, when they join together;" though the state of matters equivocally illustrated his remark, in continuation, that "it is a wise institution of our law not to settle this power any where, but rather to leave it *in dubio*, or *in nubibus*, that the people might be kept in ignorance thereof, as a thing not fit to be known nor to be pried into." Arguments founded on precedent and the nature of the constitution were at that juncture, however, merely like the diplomatic manœuvres pre-

¹ Vide Rush. Hist. Col. part iii. vol. i. 661-9.

Militia. ceding an international war. Each party was calculating its strength for the approaching conflict; and if their respective rights were so earnestly insisted on by either side, with any other view than that of colouring the real grounds of the rupture, it was that of securing the wavering by a show of adherence to constitutional principles. In a short time each party mustered its own forces in its own way.

In the parliament which was summoned after the Restoration, effectual means were taken by two statutes (13 Car. II. c. 6, and 13 and 14 Car. II. c. 3), which probably would not have been passed by the convention parliament, to put an end to any doubts as to the prerogative on this point. It was declared, that "the sole supreme government, command, and disposition of the militia, and of all forces by sea and land, and of all forts and places of strength, is, and by the laws of England ever was, the undoubted right of his majesty and his royal predecessors;" and lieutenants and their deputies were empowered to charge their counties to provide horse and foot soldiers, according to a fixed scale of property. The system thus constructed was slightly amended in the years 1699, 1714, and 1743.

In 1756, when the large standing force, which the position of Britain rendered it expedient to keep up, was made more unpopular by the introduction of the Hanoverian mercenaries, a bill to reconstruct the militia passed through the House of Commons under the auspices of Mr Charles Townshend and his friends, but was rejected in the House of Lords by 59 to 23. With some difficulty the measure was carried in 1757; but, though approved of by a large party, its practical enforcement frequently produced discontent and local disturbance. In 1762 the system was improved, and several acts were afterwards passed amending particular departments. In 1802, the militia laws of England and Scotland were consolidated by 42 Geo. III. c. 90 and 91; and these statutes, with that of 49 Geo. III. c. 120, applicable to Ireland, contain, with some partial amendments made by later acts, the law applicable to the militia of the united kingdom. Before giving such a brief selection from the many minute regulations prescribed by these statutes, as a work of general reference is expected to contain, we may be permitted to glance at the origin of the militias of Scotland and Ireland.

In Scotland there seems never to have been, except in burghs, a national force for the defence of the citizens, like the Fyrd of the Saxons. The earliest acts of parliament, however, enforce practice in the bow, of which the efficiency had been so dearly learned in the English wars; whilst periodical "wapenshawings" are directed to be held, in which each individual should be armed upon a scale vaguely proportioned to his property.¹ In time of war or rebellion, proclamations were issued, charging all sheriffs and magistrates of burghs, to direct the attendants of the respective wapenshawings to join the king's host;² and the criminal records contain many prosecutions for "abiding from" the various "raids," which are generally settled by composition with the lord treasurer. During the civil wars of the seventeenth century, the army which had been brought into existence by the enthusiasm of the covenanters, was supported by levies and assessments apportioned by district committees of war appointed by parliament, whose duties and powers were modelled on those of the commissioners of array in England. In 1662 (1 Car. II. 3, 27), the parliament made offer of 20,000 foot and 2000 horse to be at his majesty's sole disposal, and to be marched to any part of Scotland, England, or Ireland. This body constituted a regular standing army, the organization of

Militia. which underwent some alterations in the years 1669, 1672, 1693, and 1695. From this last period, no legislative improvements were made in the militia of Scotland until the year 1797, when the system established in England was partially extended to that part of the empire, though not without considerable local disturbance.

In Ireland the predatory army of gallowglasses, which, even in times of comparative tranquillity, it was found necessary to keep constantly armed for the preservation or the enlargement of the pale, was supported to a small extent by supplies from England; but it chiefly depended on exactions from the Anglo-Irish, made by a dexterous application of the many fines and petty tributes originally exigible by the native chiefs. To these the English added the formidable exactions of coign and livery, which embracing free quarters, and all that is generally taken under the sanction of that licence, were the frequent subject of bitter complaint, though not much heeded by a government which expected that the conquest would at least support itself.³ In 1715, on occasion of the rebellion in Scotland, an act was passed by the Irish parliament (2 Geo. I. c. 9) for raising a militia to consist of Protestants. Roman Catholics were subject to double rates; and all serviceable horses belonging to them might be seized and made use of, provided that within ten days the sum of L.5 (deducting the expense of seizure and keeping) was tendered to the owner of each as full payment. After several partial alterations, the militia laws were consolidated by the Irish parliament in 1793 (33 Geo. III. c. 22) and 1795 (35 Geo. III. c. 8), and accommodated to those of England in 1809.

By the present constitution of the militia in the united kingdom, his majesty appoints lords-lieutenant in England, and governors in Ireland, to each county or province, with power to call out and train the militia annually, and to appoint twenty or more deputy-lieutenants or governors, or other officers, subject to the royal approval. A deputy in England or Ireland requires, as his qualification, to be proprietor of real property worth L.200 a year, or heir apparent to an estate of twice that value. In Scotland he must possess, or be heir-apparent to, landed property to the extent of L.400 Scotch of valued rent. In England a colonel must hold an estate of L.1000 a year, or be heir-apparent to one of L.2000; in Scotland he must hold or be heir-apparent to one of L.800 of valued rent; and in Ireland he must hold an estate of L.2000 a year, or be heir-apparent to one of L.3000. A lieutenant-colonel's qualification is, in England, an annual estate of L.600, or an apparenacy of L.1200; in Scotland a valued rent of L.600; and in Ireland an estate of L.1200, or an apparenacy of L.1800. The qualifications of the lower ranks are upon a corresponding scale, personal property being taken into consideration in those of lieutenants and ensigns. There are distinct qualifications, generally of a lower grade, for Wales, the Isle of Ely, Huntingdon, Monmouth, Westmoreland, Rutland, Edinburgh, Dublin, Cork, Limerick, and those towns which are counties within themselves, and by ancient usage trained a separate militia. The militias of London and the Tower Hamlets are regulated by separate acts (viz. 36 Geo. III. c. 92, 37 Geo. III. c. 25 and 75, and 39 Geo. III. c. 92); and those of the Cinque Ports and their members are, in pursuance of ancient custom, left to the administration of the warden.

The business of balloting for and calling out the militia commences with the annual general meeting of the lieutenancy of each county, when the next subdivision meeting is appointed, to which chief constables, or other

¹ Acts, 1424, c. 18 and 44; 1425, c. 60; 1457, c. 64; 1491, c. 31; and 1540, c. 85-91.

² 1482, c. 90.

³ See Irish State Papers, published by authority of government, ii. 477, &c.

Militia. officers, are required to direct constables or schoolmasters to return lists of all males between the ages of eighteen and forty-five in their respective parishes. Within fourteen days after requisition, the constable or schoolmaster leaves a schedule in each dwelling-house, to be filled up within fourteen days, with the names and designations of persons within the ages, and their claims of exemption, if there be any, under a penalty of L.5. Within a month after serving the notices, the constables or schoolmasters make up and affix, to the church-doors, lists, mentioning exemptions and incapacities, and notifying the times and places for the discussion of appeals. These are decided by two or more deputies at the subdivision meetings, and their decisions are final. The clerks of general meetings then transmit lists to the privy council, distinguishing those liable to serve from those exempt. The men to be enrolled are chosen by ballot from each parish; all who are not above four feet and five inches in height, or are not approved of on examination by a surgeon, being discharged, and others balloted for in their room. Those who do not personally appear, or send an approved substitute to take the oath, are liable in a penalty of L.10. There are arrangements by which, with the consent of the inhabitants, volunteers, remunerated by parish assessments, may be substituted for balloted men.

The persons exempted are, peers; commissioned officers of the other forces, whether on full or half-pay; non-commissioned officers and private men in the other forces; persons serving, or who have served for four years, as commissioned officers in the militia; persons serving in the yeomanry or volunteers; persons serving, or who have served at any time within a year past, in the local militia; resident members of the several universities; clergymen of the establishments, and registered dissenting clergymen; parish schoolmasters; articulated clerks; apprentices; seafaring men; persons employed in his majesty's docks, the Tower, Woolwich Warren, the gun-wharfs of Portsmouth, and the stores under the direction of the Board of Ordnance; persons free of the company of watermen of the Thames; any poor man with more than one child born in wedlock, in England; any man with more than two lawful children, and not possessing property to the value of L.50, in Scotland; and in Ireland, any poor man not worth L.10, or who does not pay L.5 a year of rent, and has more than three lawful children under the age of fourteen.

The number of private men apportioned amongst the different countries is, for England and Wales 40,963, for Scotland 7950, and for Ireland 21,616, making a total of 70,529; but this number has been increased by temporary acts. The privy council may, at the end of every period of ten years, alter the proportional numbers assigned to the respective counties; but this arrangement has been subject to alteration by temporary acts. The annual training is, for such a period, not exceeding twenty-eight days, as his majesty may direct; and the calling out of the whole, or of any part, may be suspended by an order in council. The mutiny act and the articles of war apply to the militia so called out, with the ordinary constitutional limitation, that no punishment can extend to life or limb. There are separate provisions for recovering deserters, &c. In the case of anticipated invasion or rebellion, his majesty may direct each lord-lieutenant, or, in the case of the death or absence of a lord-lieutenant, any three of his deputies to embody the militia with all convenient speed, the occasion being first notified in parliament, if it is assembled; and if not, declared in council, and published by proclamation. By a similar proceeding, a supplementary militia may be raised, to the extent of one half of the fixed number. The regiments are liable to be marched to any part of the united kingdom; but no Irish regiment

can be compelled to serve in Britain, or British regiment in Ireland, longer than two years at one time; nor must above a fourth part of the British militia be employed in Ireland, or a third of the Irish militia in Britain. These restrictions, adopted in 1811, when the militias of the two islands were united under the title of the Militia of the United Kingdom, were partially suspended in 1813; and during the time of actual invasion or rebellion they may be disregarded. The old principle, that the militia cannot be compelled to serve out of the kingdom, is still adhered to, although in 1813 (54 Geo. III. c. 1) provision was made for accepting the service of militiamen and officers, to be formed into provisional regiments, and to co-operate with the regular forces. At previous periods, considerable numbers of militiamen had been drafted into the line, the losses of the militia regiments being made up by temporary acts, which slightly increased their original quotas.

By 48 Geo. III. c. 111 and 150, the celebrated local militia was, in 1808, appointed in England and Scotland, being limited in each county to "six times the original quota or proportion of the original quota of militia." In 1812, two new acts were passed (52 Geo. III. c. 38 and 68), which apportioned the numbers of men to the respective shires in England and Scotland, but contained regulating provisions which tended to make the local militia and volunteers together amount to six times the number of the original militia contingents. When these forces were added to the two hundred thousand men allowed to be trained by Mr Windham's act (46 Geo. III. c. 90), the citizen army, at the disposal of government in Great Britain, amounted, independently of the militia, &c. of Ireland, and of temporary augmentations, to very nearly five hundred thousand men. In 1811, the effective strength of the regular militia was 77,424 private men, whilst that of the local militia was 213,609. In 1819, the disembodied militia of Britain and Ireland, calculated from the estimates of the year, amounted in round numbers to 71,200; and in 1829, it amounted to 70,082, private men and drummers.

The balloting, enrolling, and exercising of the militia now only takes place at occasional periods, an act being generally passed during each session, suspending their annual recurrence. By 10 Geo. IV. c. 10, the staff of the disembodied militia was reduced; and, according to a recent return, amounted, after the reduction, to 127 adjutants, 127 serjeant-majors, 1692 serjeants, 82 drum-majors, and 669 drummers. A further reduction was authorized by 5 and 6 Wil. IV. c. 37, and made by an order in council of the 10th October 1835. It appears from a return to the House of Commons of the 7th July 1836, that the staff of the militia of the united kingdom at present receiving pay amounts to 119 adjutants, 123 serjeant-majors, and 845 serjeants. The cost of the militia of the united kingdom, including the half-pay of officers and non-commissioned officers, during each of the last three quarters of the year ending 31st March 1836, was, for the quarter ending 30th September 1835, L.25,985. 8s. 5½d; for that ending 31st December 1835, L.37,139. 8s. 4d.; and for that ending 31st March 1836, L.32,219. 16s. 10d. According to the estimates for 1836-37, the number of private men is, in Great Britain, 50,888; in Ireland 18,525. (M. M. M. M.)

MILK, a well-known fluid, prepared by nature in the breasts of women, and the udders of other animals, for the nourishment of their young.

According to Dr Cullen, milk is a connecting and intermediate substance between animals and vegetables. It seems to be immediately secreted from the chyle, both being a white liquor of the same consistence; it is most copiously secreted after meals, and is of an acescent nature. In most animals which live on vegetables the milk is acescent; and it is uncertain whether it is not so likewise in carnivorous animals. But, whatever there be in this, it is

Milk.

Milk. certain that the milk of all animals which live on vegetables is acescent. Milk being derived from the chyle, we thence infer its vegetable nature; for in those who live on both promiscuously, a greater quantity of milk is obtained, and more quickly, from the vegetable than from the animal food. Milk, however, is not purely vegetable, though we have a vegetable liquor which resembles it in taste, consistence, colour, acescency, and the separability of the oily part, viz. an emulsion of the *nucis oleosæ* and farinaceous substances. But these want the coagulable part of milk, which seems to be of an animal nature, approaching to that of the coagulable lymph of the blood. Milk, then, appears to be of an intermediate nature between chyle taken up from the intestines and the fully elaborated animal fluid.

Its contents are of three kinds. First, there is an oily part, which, whatever may be said concerning the origin of other oils in the body, is certainly immediately derived from the oil of the vegetables taken into the stomach; for with these it agrees very exactly in its nature, and would do so entirely, if we could separate it fully from the coagulable part. Another mark of their agreement is the separability, which proves that the mixture has been lately attempted, but not fully performed. Secondly, besides this oily, there is a proper coagulable part. And, thirdly, much water accompanies both, in which there is dissolved a salino-saccharine substance. These three can be got separate in cheese, butter, and whey; but never perfectly so, a part of each being always blended with every other part.

Nothing is more common, from what has been said of its immediate nature, than to suppose that it requires no assimilation; and hence has been deduced the reason of its exhibition in the most weakly state of the human body. But wherever we can examine milk, we always find that it coagulates, suffers a decomposition, and becomes acescent. Again, infants, who feed entirely on milk, are always troubled with eructations, which every body observes are not of the same quality with the food taken; and therefore it appears, that, like all other food, milk turns naturally acescent in the stomach, and only enters the chyle and blood in consequence of a new recombination. It approaches then to the nature of vegetable aliment, but is not capable of its noxious vinous fermentation, and therefore has an advantage over it. Neither, from this quality, is it like animal food, heating in the stomach, and productive of fever, though at the same time, from its quantity of coagulable matter, it is more nourishing than vegetables.

Milk is the food most universally suited to all ages and states of the body; but it seems chiefly designed by nature as the food of infants. When animals are in the foetal state, their solids are a perfect jelly, incapable of an assimilatory power. In such state nature has perfectly assimilated food, as the *albumen ovi* in the oviparous, and in the viviparous animals certainly somewhat of the same kind, as it was necessary that the vessels should be filled with such a fluid as would make way for an after assimilation. When the infant has attained a considerable degree of firmness, as when it is separated from the mother, such a degree of weakness still remains as makes somewhat of the same indication necessary; it behoves the infant to have an alkaline food ready prepared, and, at the same time, its noxious tendency to be avoided. Milk then is given, which is alkaline, and, at the same time, has a sufficient quantity of acidity to correct the alkaline quality. As the body advances in growth, and the alkaline tendency is greater, the animal, to obviate that tendency, is led to take vegetable food, as more suited to its strength of assimilation.

Dr Cullen observes, that milk is suited to almost all temperaments; and it is so to stomachs disposed to acescency, more than those substances which have undergone the vinous fermentation; nay, it even cures the heartburn,

checks vinous fermentation, and precipitates the lees, when, by renewal of fermentation, the wine happens to be fouled. It, therefore, very properly accompanies a great deal of vegetable aliment; although sometimes its acescency is troublesome, either from the large portion taken in, or from the degree of it; for, according to certain unaccountable circumstances, different acids are formed in the stomach in different states of the body, as in a healthy body a mild one, and in the hypochondriac disease one of a very acrid quality. When the acidity of milk is carried to a great degree, it may prove remarkably refrigerant, and occasion cold crudities, and the recurrence of intermittent fevers. To take the common notion of its passing unchanged into the blood, it can undergo no solution. But if we admit its coagulum in the stomach, then it may be reckoned amongst soluble or insoluble foods, according as that coagulum is more or less tenacious. Formerly rennet, which is employed to coagulate milk, was thought an acid; but, from late observations, it appears, that, if it be an acid, it is very different from other acids, and that its coagulum is stronger than that produced by acids. It has been imagined that a rennet, which causes coagulation of milk, is to be found in the stomachs of all animals; but according to Dr Cullen, the coagulation of milk seems to be owing to a weak acid in the stomach, the relics of vegetable food, inducing, in healthy persons, a weak and soluble coagulum; but in different stomachs this may be very different, in some becoming heavy and less soluble food, and may even be evacuated in a coagulated undissolved state both by stomach and stool.

As milk is acescent, it may be rendered purgative by mixture with the bile. Some examples of this have been remarked. But it is more commonly reckoned amongst those foods which occasion costiveness.

Hoffman, in his experiments upon milk, ascertained that all kinds of it contained much water; and when this was dissipated, he found the residuums very different in their solubility. But we must not thence conclude, that the same insolubility takes place in the stomach; for extracts made from vegetables with water are often very insoluble substances, and hardly diffusible through water itself. In Hoffman's extracts of milk, therefore, somewhat of the same kind might have appeared; and these substances, which in their natural state were not so, might appear very insoluble. However, we may allow that milk is always somehow insoluble in the intestines, as it is of a drying nature, and as cheese is very costive. And this effect shows that milk is always coagulated in the stomach; for if it remained fluid, no fæces would be produced, whereas sometimes very hard ones are observed. In the blood-vessels it may, from its animal nature, be considered as nutritious; but when we consider its vegetable contents, and acescency in the *primæ viæ*, we find that, like animal food, it does not excite that degree of fever in the time of digestion, and that from its acescency it will resist putrefaction. Hence its use in hectic fevers, which, whatever be their cause, appear only to be exacerbations of natural feverish paroxysms, which occur twice every day, commonly after meals, and at night. To obviate these, therefore, we give such an aliment as produces the least exacerbation of these fevers; and of this nature is milk, on account of its acescent vegetable nature.

There also appears something peculiar to milk, which requires only a small exertion of the animal powers in order to its assimilation; and besides, in hectic complaints, there is wanted an oily, bland food, approaching to the animal nature; so that upon all these accounts milk is a diet peculiarly adapted to them, and, in general, to most convalescents, and to those of inflammatory temperaments.

The milks of women, mares, and asses, in a great measure agree in their qualities, being very dilute, having little

Milk.

Milk. solid contents, and these, when evaporated to dryness, being very soluble, and containing much saccharine matter of a very ready acescency, and their coagulum being tender and easily broken down. From this view they have less oil, and seem to have less coagulable matter than the rest.

The milks of cows, sheep, and goats, agree in possessing qualities opposite to those just mentioned; but here there is somewhat more of gradation. Cow's milk comes nearest to the former. Goat's milk is less fluid, less sweet, less flatulent, and has the largest proportion of insoluble part after coagulation, and indeed the largest proportion of coagulable part; its oily and coagulable parts are not spontaneously separable, and it never throws out a cream, or admits of butter to be readily extracted from it. Hence the virtues of these milks are obvious, being more nourishing, though at the same time less easily soluble in weak stomachs, than the three kinds above mentioned, less acescent, and more rarely laxative, and peculiarly fitted for the diet of convalescents without fever. The other kinds again are less nourishing, more soluble, more laxative, from being more acescent, and adapted to convalescents with fever.

These qualities in particular milks are considerably diversified by different circumstances. First, different animals living on the same diet give a considerably different milk; for there seems to be something in the constitution, abstracting from the aliment, which constitutes a considerable diversity of milk, not only in the same species of animals, but also in the same animal, at different ages, and at different intervals after delivery. This also applies to the choice of nurses. Secondly, milk follows the nature of the aliment more than any other juice in the human body, being more or less fluid and dilute, and more or less solid and nourishing, in proportion as these qualities are more or less in the aliment. The nature of the aliment differs according to its time of growth, old grass being always found more nourishing than young. Aliment, too, is always varied according to the season, as that is warm or dry, moist or cloudy.

The milk of each particular kind of animal is fitter for particular purposes, when fed on proper food. Thus the cow delights in the succulent herbage of the valley; if the sheep be fed there he certainly rots, but on the higher and more dry side of the mountain he feeds pleasantly and healthily; whilst the goat never stops near the bottom, but ascends to the craggy summit. The milks of these animals, therefore, are always best upon their proper soil; and that of goats is best in a mountainous country. In a dissertation of Linnæus, we find many observations concerning the diversity of plants on which each animal chuses to feed. All the Swedish plants which could be collected together were presented alternately to domestic animals, and then it appeared that the goat lived on the greatest variety, and even on many which were poisonous to the rest; and that the cow chose the first succulent shoots of the plant, and neglected the fructification, which was preferred by the goat. Hence may be deduced rules concerning the pasturage of different animals. Thus farmers find, that, in a pasture which was only fit to feed a certain number of sheep, an equal number of goats may be introduced, whilst the sheep are no less nourished than before.

It is not easy to assign the difference between milk fresh drawn and that detained in the open air for some time; but certainly there is some material one, otherwise nature would not have directed infants universally to sucking; and indeed it seems better fitted for digestion and nourishment than the other. Physicians have supposed that this depended on the evaporation of some spirit; but Linnæus cannot conceive any thing except common water here; and besides, these volatile parts can hardly be nutritious. A more plausible account seems deducible from mixture.

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Milk. Milk newly drawn and recently mixed is exposed to spontaneous separation, a circumstance hurtful to digestion; none of the parts being, by themselves, so easily assimilated as when they are all taken together. Hence milk newly drawn is more intimately blended, and therefore is most proper to weak persons and to infants.

Another difference in the use of milk exposed for some time to the air, is taking it boiled or unboiled. Physicians have generally recommended the former; but the reason is not easily assigned. Perhaps it may be that milk kept for some time exposed to the air has gone so far towards a spontaneous separation; whereas the heat thoroughly blends the whole, and hence its resolution is not so easy in the stomach; and thus boiled milk is more costive than raw, and gives more fæces. Again, when milk is boiled, a considerable quantity of air is detached, as appears from the froth on the surface; and air is the chief instrument of fermentation in bodies; so that after this process it is not liable to acescency. For these reasons it is proper for the robust and vigorous.

Another difference of milk is, according as it is fluid or coagulated. The coagulated is of two kinds; either as induced by rennet, or occasioned by the natural acescency of the milk. The former preparation makes the firmer and less easily soluble coagulum; but, when taken with the whey unseparated, it is less difficult of solution, though more so than any other coagulum in the same case. Many nations use the latter form, which is more easily soluble, but very acescent, and therefore, in point of solution, should be confined to the vigorous, or to those who live on alkaline food; in fact, the Laplanders use it as their chief acescent condiment. From the same considerations it is more cooling, and in its other effects it is similar to all other acescent vegetables.

Milk by evaporation yields a sweet saline matter, of which Dr Lewis gives the following proportions:

Twelve Ounces of	Left of Dry Matter.	From which Water extracted a Sweet Saline Substance amounting to
Cow's milk...	13 drachms.	1½ drachm.
Goat's milk...	12½	1½
Human milk.	8	6
Ass's milk....	8	6

The saline substance extracted from ass's milk was white, and as sweet as sugar; that of the others was brown or yellow, and considerably less sweet; that from cow's milk had the least sweetness of any.

On distilling twelve quarts of milk in *balneo marie*, at least nine quarts of pure phlegm were obtained. The liquor which afterwards arose was acidulous, and by degrees grew sensibly more and more acid as the distillation was continued. After this came over a little spirit, and at last the empyreumatic oil. The remaining solid matter adhered to the bottom of the retort, in the form of elegant shining black flowers, which being calcined and elixated, yielded a portion of fixed alkaline salt.

Milk set in a warm place throws up to the surface an unctuous cream, from which, by agitation, the butter is easily separated. The addition of alkaline salts prevents this separation, not, as some have supposed, by absorbing an acid from the milk, but by virtue of their property of intimately uniting oily bodies with watery substances. Sugar, another intermedium between oils and water, has this effect in a greater degree, though that concrete is by no means alkaline, nor an absorbent of acids.

The sweet saccharine part of the milk remains dissolved in the whey after the separation of the curd or fromaginous matter, and may be collected from it in a white crys-

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Milk. talline form, by boiling the whey till all remains of the curdled substance have fallen to the bottom; then filtering, evaporating it to a due consistence, setting it to shoot, and purifying the crystals by solution in water and a second crystallization. Much has been said of the medicinal virtues of this sugar of milk, but it does not seem to have any that are considerable. It is from cow's milk that it has been generally prepared; and the crystals obtained from this kind have but little sweetness.

When milk is suffered to coagulate spontaneously, the whey proves acid, and on standing grows more and more so until the putrefactive state commences. Sour whey is used as an acid, preferable to the directly vegetable or the mineral acids, in some of the chemical arts, as for dissolving iron in order to stain linen and leather. In the bleaching of linen this acid was commonly made use of for dissolving and extracting the earthy particles left in the cloth by the alkaline salts and lime employed for cleansing and whitening it. Butter milk is preferred to plain sour milk or sour whey, being supposed to give the cloth a yellow colour. Dr Home, in his treatise on this subject, recommends water acidulated with sulphuric acid, in the proportion of about half an ounce, or at most three quarters of an ounce, to a gallon, as preferable in many respects to the acid of milk, or that of any directly vegetable substance. He observes, that the latter are often difficult to be procured, abound with oleaginous particles, and hasten to corruption, whilst the vitriolic acid is cheap and pure, without any tendency to putrify; that milk takes five days to perform its office, whilst the vitriolic acid does it in as many hours, perhaps in as many minutes; and that this acid contributes also to whiten the cloth, and does not make it weaker though the cloth be kept in it for months. He states, that acids, as well as alkalies, extract an oily matter from the cloth, and lose their acidity and alkalinity. Since this treatise appeared, the use of sour milk has been entirely superseded by sulphuric acid.

It is observable, that ass's milk has a great tendency, on standing for a little time, to become thick and ropy. In the Breslau collection for the year 1720, there is a remarkable account of milk which had grown so thick and tenacious as to be drawn out into long strings.

New cow's milk, suffered to stand for some days on the leaves of butterwort or sun-dew, becomes uniformly thick, slippery, and coherent, and of an agreeable sweet taste, without any separation of its parts. Fresh milk added to this is thickened in the same manner, and this successively. In some parts of Sweden, milk is thus prepared for food.

New milk has a certain glutinous quality, in consequence of which it is used for joining broken stone ware. There is a far greater tenacity in cheese properly prepared.

Milk, when examined by a microscope, appears composed of numerous globules swimming in a transparent fluid. It boils in nearly the same degree of heat with common water; some sorts rather sooner, and others a little later. After boiling it has less tendency to become sour than in its natural state. It is coagulated by acids both mineral and vegetable, and by alkalies both fixed and volatile. The coagulum produced by acids falls to the bottom of the serum; that made by alkalies swims on the surface, commonly forming a thick coriaceous skin, especially with volatile alkalies. The serum, with alkalies, proves green or sanious; with acids, it differs little in appearance from the whey which separates spontaneously. The coagulum formed by acids is dissolved by alkalies, and that formed by alkalies is redissolved by acids; but the milk does not in either case resume its original properties. It is coagulated by most of the middle salts, the basis of which is an earth or a metallic body, as solution of alum, fixed sal-ammoniac, sugar of lead, green and blue vitriol; but not by the chalybeate or purging mineral waters, nor by the bit-

Milk. ter salt extracted from the purging waters. Amongst the neutral salts which have been tried, there is not one that produces any coagulation. They all dilute the milk, and make it less disposed to coagulate with acids or alkalies. Nitre seems to have this effect in a greater degree than the other neutral salts. It is instantly coagulated by highly rectified spirit of wine, but scarcely by a phlegmatic spirit. It does not mingle with expressed oils. All the coagula are dissolved by gall.

It has generally been supposed by medical authors, that the milk of animals is of the same nature with chyle, and that the human milk always coagulates in the stomach of infants; but in a dissertation upon the subject published by Mr Clarke, member of the Royal Irish Academy, we find both these positions controverted. According to him, women's milk, in a healthy state, contains no coagulable, mucilaginous, or fromaginous principle, in its composition, or it contains so little, that it cannot admit of any sensible proof. Dr Ruttly states, that it does not afford even a sixth part of the curd which is yielded by cow's milk; and Dr Young denies that it is at all coagulable either by rennets or acids. This is confirmed by Dr Ferris, who, in the year 1782, gained the Harveian prize medal by a dissertation upon milk. Mr Clarke informs us, that he made a great number of experiments upon women's milk, with a view to determine this point. He made use of ardent spirits, all the different acids, infusions of infants' stomachs, and procured the milk of a great many different women; but in no instance, excepting one or two, did he perceive any thing like curd. This took place in consequence of a spontaneous acescency; and only a small quantity of soft flaky matter was formed, which floated in the serum. This he looked upon as a morbid appearance.

The general opinion that women's milk is coagulable has arisen from the single circumstance that infants frequently vomit the milk which they suck in a state of apparent coagulation. This greatly perplexed Dr Young, who, after having tried in vain to coagulate human milk artificially, concluded that the process took place spontaneously in the stomach; and that it would always do so if the milk were allowed to remain in a degree of heat equal to about 96° of Fahrenheit. Mr Clarke took equal quantities of three different kinds of milk, and put them into bottles slightly corked, and these bottles into water, the temperature of which was kept up by a spirit of wine lamp as near as possible to 96° of Fahrenheit; but after frequently examining each bottle during the course of the experiment, at the expiration of several hours there was not the smallest tendency towards coagulation to be perceived in any of them. The cream was only thrown to the surface in a thick and adhesive form, and entirely separated from the fluid below, which had something of a grey and wheyish appearance. As the matter vomited by infants is sometimes more adhesive than we can suppose cream to be, Mr Clarke supposed that the curd might be so entangled with the cream as to be with difficulty separated from it; but having collected a quantity of rich cream from the milk of different women, he repeated the experiment with precisely the same result, not being able in any one instance to produce the smallest quantity of curd. To determine, however, what effects might be produced upon milk by the stomach of an infant, Mr Clarke made the following experiment. Having taken out the stomach of a foetus which had been deprived of life by the use of instruments, he infused it in a small quantity of hot water, so as to make a strong infusion. He added a tea-spoonful of this infusion to equal quantities of cow's and human milk, the consequence of which was, that the cow's milk was firmly coagulated in a short time, but the human milk was not altered in the least; neither was the least coagulation produced by adding a second and a third spoonful to the human milk. "Upon

Milk. the whole, then," says he "I am persuaded it will be found that human milk, in a healthy state, contains little or no curd, and that the general opinion of its nature and properties is founded upon fallacious analogy and superficial observations made on the matter vomited by infants. We may presume, that the cream of women's milk, by its inferior specific gravity, will swim on the surface of the contents of the stomach; and being of an oily nature, that it will be of more difficult digestion than any other constituent part of milk. When an infant, then, sucks very plentifully, so as to over-distend the stomach, or labours under any weakness in the powers of digestion, it cannot appear unreasonable to suppose that the cream shall be first rejected by vomiting. Analogous to this, we know that adults affected with dyspepsia often bring up greasy fluids from the stomach by eructation, and this especially after eating fat meat. We have, in some instances, known this to blaze, when thrown into the fire, like spirit of wine or oil." Of this opinion he derives a confirmation from the observation, that curds vomited by infants of a few days old are yellow, whilst in the course of a fortnight or three weeks they become white. This he accounts for from the yellow colour of the cream thrown up by the milk of women during the first four or five days after delivery.

Mr Clarke likewise controverts the common opinion, that human milk is so prone to acidity that a great number of the diseases of children are to be accounted for from that cause. "Whoever," says he, "takes the trouble of attentively comparing human milk with that of ruminant animals, will soon find it to be much less prone to run into the acescent or acid process. I have very often exposed equal quantities of human and cow's milk in degrees of temperature varying from the common summer heat, or 65°, to 100°; and I have constantly found that cow's milk acquires a greater degree of acidity in thirty-six hours than the human did in many days. Cow's milk becomes offensively putrid in four or five days; a change which healthy human milk, exposed in the same manner, will not undergo in many weeks, nay, sometimes in many months. I once kept a few ounces of a nurse's milk, delivered about six or seven days, for more than two years in a bottle moderately corked. It stood on the chimney-piece, and was frequently opened to be examined. At the end of this period, it showed evident marks of moderate acidity, whether examined by the taste, smell, or paper stained with vegetable blues or purples; the latter it changed to a florid red colour; whereas cow's milk kept a few days changed the colour of the same paper to a green, thereby clearly showing its putrescent tendency."

He next proceeds to consider the probability there is of milk becoming so frequently and strongly acid as to occasion most of the diseases of infants. He begins with an attempt to show that the phenomena commonly regarded as indications of acrimony are by no means certain. Curdled milk has already been shown to be no sign of acidity; and the other appearance, which has commonly been thought to be so certain, namely, green fæces, is, in the opinion of Mr Clarke, equally fallacious. In support of this he quotes a letter from Dr Sydenham to Dr Cole, in which the former says, that the green matter vomited by hysterical women is not any proof of acrid humours being the cause of that disease, for sea-sick people do the same. The opinion that green fæces are an effect of acidity, proceeds upon the supposition that a mixture of bile with an acid produces a green colour; but it is found that the vegetable acid, which only can exist in the human body, is unable to produce this change of colour, though it can be effected by the strong mineral acids. As nothing equivalent to any of these acids can be supposed to exist in the bowels of infants, we must therefore adopt some other method of accounting for the green fæces frequently eva-

cuated by them. "Why should sour milk, granting its existence, give rise to them in infants, and not in adults? Have butter-milk, summer fruits of the most acescent kind, lemon or orange juice, always this effect in adults by their admixture with bile? This is a question which, I believe, cannot be answered in the affirmative."

Upon the whole, Mr Clarke considers the disease of acidity in the bowels, though so frequently mentioned, as by no means common. He owns, indeed, that it may sometimes occur in infancy as well as in adult age, from weakness of the stomach, costiveness, or improper food; and an indubitable evidence is afforded by fæces which stain the blue or purple colour of vegetables to a red, though nothing can be inferred with certainty from the colour or smell.

He then proceeds to state several reasons for his opinion, that the greater number of infantile diseases are not owing to acidity. First, women's milk, in a healthy state, contains little or no coagulable matter or curd. Secondly, it shows less tendency out of the body to become acescent than many other kinds of milk. Thirdly, the appearances which have been generally supposed to characterize its acidity do not afford satisfactory evidence of such a morbid cause. Fourthly, granting this to be the case, we have plenty of mild absorbents, capable of destroying all the acid which can be supposed to be generated in the bowels of an infant; yet many children are observed to die in consequence of these diseases, which are supposed to arise from acidity. Fifthly, though the milk of all ruminant animals is of a much more acescent nature than that of the human species, yet the young of these animals never suffer any thing like the diseases attributed to acidity in infants. Sixthly, history informs us that whole nations use sour curdled milk as a considerable part of their food, without feeling any inconvenience; which, however, must have been the case if acidity in the stomach were productive of such deleterious effect as has been supposed. This reasoning appears to be very plausible, and nothing has as yet been offered to contradict it.

In a memoir by MM. Parmentier and Deyeux, members of the Royal College of Pharmacy in Paris, we have an account of a great number of experiments on the milk of asses, cows, goats, sheep, and mares, as well as women. The experiments on cow's milk were made with a view to determine whether any change was produced in the milk by the different kinds of food eaten by the animal. For this purpose some were fed with the leaves of maize, others with cabbage, others with small potatoes, and others with common grass. The milk of those fed with the maize was extremely sweet; that from the potatoes and common grass was much more serous and insipid; and that from the cabbages proved the most disagreeable of all. By distillation only eight ounces of a colourless fluid were obtained from as many pounds of each of these milks; that obtained from those which fed upon grass had an aromatic flavour; whilst a disagreeable one resulted from cabbage, and none at all from the potatoes and maize. This liquid became fetid in the space of a month, whatever substance the animal had been fed with, acquiring at the same time a viscosity, and becoming turbid; that from cabbage generally, but not always, becoming first putrid. All of them separated a filamentous matter, and became clear on being exposed to the heat of 25° of Reaumur's thermometer. In the residuum of distillation no difference whatever could be perceived. As the only difference therefore existing in cow's milk consists in the volatile part, our authors conclude that it is improper to boil milk either for common or medicinal purposes. They observed also that any sudden change of food, even from a worse to a better kind, was attended by a very remarkable diminution in the quantity of milk. The residuum of the distillation yielded, in a strong fire, a yellow oil and acid, a thick and black em-

Milk.

Milk.

pyreumatic oil, a volatile alkali, and towards the end a quantity of inflammable air, and at last a coal remained containing some fixed alkali with muriatic acid.

On agitating in long bottles the cream from the milk of cows fed with different substances, all of them were formed into a kind of half-made butter, of which that formed from the milk of maize was white, firm, and insipid, that from potatoes was softer and more pinguetous, and that from common grass was the best of all. Cabbage, as in other cases, gave a strong taste.

In the course of these experiments, an endeavour was made to determine whether butter is actually contained in the cream, or whether it be a chemical production of the operation of churning. They could not find any reason absolutely satisfactory on either side, but incline to the latter opinion; because when cream has been allowed to remain amongst the milk, and the whole curdled promiscuously, fat cheese, without any butter, is produced. The oily parts cannot be separated into butter either by acids or any other means than churning; even the artificial mixture of oil with the cream is insufficient for the purpose.

The serum of milk was reduced by filtration to a clear and pellucid liquor; and, by mixture with fixed alkali, it deposited a portion of fromaginous matter which had been dissolved in the whey. The sugar of milk was also found in this liquor.

In these experiments upon the milk of various animals, it was found that that of asses yielded by distillation an insipid liquor, and deposited a liquor similar to the lymph of cow's milk. This kind is coagulated by all the acids, but not into an uniform mass, exhibiting only the appearance of distinct flocculi. It affords but little cream, which is with difficulty converted into a soft butter, that soon becomes rancid. It has but a small quantity of saccharine particles, and these are often mixed with muriatic selenite and common salt. Goat's milk has a thick cream, which is agreeable to the taste; and the milk itself may be preserved longer in a sound state than any other species, the scum on its surface being naturally convertible into palatable cheese. It is easily made into firm butter, which does not soon become rancid, and has a good flavour. The butter-milk contains a large quantity of fromaginous matter, which readily coagulates; but it has still less saccharine matter than that of asses. Sheep's milk can scarcely be distinguished from that of a cow, and easily parts with its cream by standing. It is of a yellow colour, of an agreeable flavour, and yields a great proportion of butter; but this is not solid, and soon becomes rancid. Mare's milk is the most insipid and least nutritious of any, notwithstanding which it has been much recommended for weak and consumptive patients. It is probable that, in such cases, it proves efficacious by being more consonant than any other to the debilitated powers of digestion. It boils with a smaller fire than any other kind of milk, is easily coagulated, and the distilled water does not so soon change its nature. It has but a small quantity of fromaginous matter, and very few oily particles. The cream cannot be made into butter; and the whey contains about as much sugar as cow's or goat's milk.

It has also been remarked, that in order to augment the quantity, as well as to improve the quality, of the milk of animals, they should be well fed, their stalls kept clean, and their litter frequently renewed. They should be milked at stated hours, but not drained; and great attention should be paid to the breed, because inferior cattle are maintained at as great expense as the most valuable kinds. No change ought to be made in the food; although, if the milk be employed for medicinal purposes, it may be improved by a proper mixture of herbs.

In their experiments on women's milk, MM. Parmen- tier and Deyeux differ somewhat from Mr Clarke. They

first tried the milk of a woman who had been delivered four months before, and observed that, after the cream had been separated, the other part appeared of a more perfect white, and that it could not be coagulated either by vinegar or mineral acids, a circumstance which they attributed to a superabundance of serum. But they found that in proportion to the age of the milk it was more easily coagulable; and this was confirmed by experiments made upon the milk of twenty nurses. Its coagulability was not increased by heat. The cream, by agitation, formed a viscid unctuous matter, which, however, could not be changed into perfect butter; but they found it extremely difficult to determine the proportions of the various component parts of human milk, as it differs remarkably, not only in different subjects, but in the same subject at different times. In a nurse aged about thirty-two years, who was extremely subject to nervous affections, the milk was one day found almost quite colourless and transparent; in two hours afterwards, a second quantity drawn from the breast was viscid like the white of an egg; and in a short time it became whiter, but did not recover its natural colour until the evening. It was afterwards found that these changes were occasioned by the woman having in the mean time had some violent hysterical fits.

MILK of Vegetables. For the same reason that the milk of animals may be considered as a true animal emulsient, the liquors of vegetables may be termed *vegetable milks*. Accordingly emulsions made with almonds are commonly called *milk of almonds*. But besides this vegetable milk, which is in some measure artificial, many plants and trees contain naturally a large quantity of emulsive or milky juices. Of this kind are lettuce, spurge, fig-tree, and the tree which furnishes the elastic American resin. The milky juices obtained from all these vegetables derive their whiteness from an oily matter, mixed and undissolved in a watery or mucilaginous liquor. Most resinous gums are originally such milky juices, which afterwards become solid by the evaporation of their more fluid and volatile parts.

MILKY WAY, or Via Lactea. See ASTRONOMY.

MILL, a machine for grinding corn and other kinds of grain. There are various kinds of mills, according to the different methods of applying the moving power, as water-mills, wind-mills, mills worked by horses, and others. See MECHANICS.

The first obvious method of reducing corn into flour for bread would be by the simple expedient of pounding; and for ages this was the only one practised by the various descendants of Adam. The same method continued in use amongst the Romans until after the reign of Vespasian. But the process was very early improved by the application of a grinding power, and the introduction of mill-stones. This, like most of the common refinements in domestic life, was probably the invention of the antediluvian world; it certainly was practised in some of the earliest ages after the Deluge; and, like most of them, it was equally known in the East and the West. Hence the Gauls and Britons appear to have been familiarly acquainted with the use of hand-mills before the time of their submission to the Romans; the Britons particularly distinguished them, as the Highlanders do at present, by the simple appellations of *querns*, *carries*, or *stones*. To these the Romans added the very useful invention of water-mills. For this discovery the world is indebted to the genius of Italy; and, at the conquest of Lancashire, the machine was not uncommon in the country. This the Romans introduced along with their other refinements. The British appellation of a *water-mill* suggests this of itself; the *melin* of the Welsh and Cornish; the *mull*, *meill*, and *melin* of the Armoricans; and the Irish *muilean* and *muilind*, being all evidently derived from the Roman *mola* and *molendinum*.

Milk
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Mill.

Mill. The subject Britons universally adopted the Roman name, but applied it, as their successors did, only to the Roman mill; and one of these was probably erected at every station or city in the kingdom. There was one at Manchester, which served equally the purposes of the town and the accommodation of the garrison. This water-mill was fixed immediately below the Castlefield and the town, on the channel of the Medlock. There, a little above the ancient ford, the sluice of it was accidentally discovered about half a century ago.

During the first five or six centuries of Rome, there were no public bread-bakers in the imperial city. They were first introduced from the East, at the conclusion of the war with Perseus, about the year 167 before Christ; and, towards the close of the first century, the Roman families were supplied by them every morning with fresh loaves for breakfast. But the same custom, which prevailed originally amongst the Romans and many other nations, continued long afterwards amongst the Mancunians. The providing of bread for every family was left entirely to the attention of the women; and it was baked upon stones, which the Welsh denominate *greidiols*, and we *gredles*. It appears, however, from the kiln-burned pottery which has been discovered in the British sepulchres, and from the British appellation of an *odyn* or *oven* remaining amongst us at present, that furnaces for baking were generally known amongst the aboriginal Britons. An *odyn* would, therefore, be erected in the mansion of each British baron, for the use of himself and his retainers; and when he and they removed into the vicinity of a Roman station, the oven would be rebuilt with the mansion. One bakehouse would be constructed, as we have previously shown one mill to have been set up, for the public service of all the Mancunian families. It appears that one oven and one mill were established in the town, and that the inhabitants were immemorially accustomed to bake at the one and grind at the other. Both, therefore, were in all probability constructed at the first introduction of water-mills and ovens into the country. The great similarity of the appointments refers directly to one and the same origin; indeed, the general nature of all such institutions points immediately to the first and actual introduction of both. And, as the same establishments prevailed equally in other parts of the north, and pretty certainly obtained over the whole extent of Roman Britain, the same erections were as certainly made at every stationary town in the kingdom.

MILL, JAMES, author of the History of British India, and various other valuable works, was born on the 6th of April 1773, in the parish of Logie Pert, in the county of Forfar, at a place situated about seven miles from Montrose. His father united the occupations of shoemaker and small farmer. He received the first part of his education at the parochial school of Logie Pert, and afterwards at the grammar school of Montrose.

Some pious ladies, amongst whom was Lady Jane Stuart, wife of Sir John Stuart, Bart. of Fettercairn, a place situate a few miles distant from that of his birth, having established a fund for educating one or two young men for the Church, Lady Jane¹ applied to the Rev. Mr Foote, minister of Fettercairn, to recommend one for that profession. Mr Foote in his turn applied to the Rev. Mr Peters, minister of Logie Pert, who recommended James Mill, both on account of his own abilities, and the known good character of his parents. He was accordingly sent to the university of Edinburgh, where he went through the course of study necessary for admission into the Church of Scotland, and

was, in due time, licensed as a Preacher in the usual form. He did not obtain any living in the church, and never, perhaps, had any particular liking for the profession, into which he was thrown more by accident than choice. The study which chiefly delighted him, and exercised his thoughts, during the period of his academical course, was that of Metaphysical and Ethical Philosophy. The class of Moral Philosophy, which, in the arrangements of the university of Edinburgh, embraces the whole field of the philosophy of mind, was then taught by Mr Dugald Stewart, to whose noble eloquence, and animated exhortations to mental study, Mr Mill always listened with profound attention, and rapturous admiration. In a letter to one of his friends, written long after this period, namely, in 1821, when he had himself become greatly distinguished, he thus expresses his obligations to the lectures of that illustrious Professor:—"All the years I remained about Edinburgh, I used, as often as I possibly could, to steal into Mr Stewart's class to hear a lecture, which always was a high treat. I have heard Pitt and Fox deliver some of their most admired speeches; but I never heard any thing nearly so eloquent as some of the lectures of Professor Stewart. *The taste for the studies which have formed my favourite pursuits, and which will be so to the end of my life, I owe to him.*" This acknowledgment was the more creditable to Mr Mill, that he had by this time widely separated from that metaphysical school of which Mr Stewart was the greatest ornament.

Mr Mill removed to London soon after the commencement of the present century; but before doing so, he seems to have officiated for a considerable time as a private tutor in the families of one or two gentlemen of fortune and consideration; and he appears also to have formed friendships with some young men, who afterwards distinguished themselves in science and literature. From the period of his arrival in the metropolis, till the year 1819, when he received, much to the honour of the donors, a valuable appointment in the India House, he supported himself and his growing family (for he married in 1805) entirely by his pen. We scarcely know any similar instance of a mere literary adventurer, without any profession or calling of any sort, maintaining himself and a large family for such a length of time, and preserving, as he unquestionably did, a character of the highest respectability, and lofty independence of thinking and writing. He not only supported his family without ever asking a favour, or incurring a debt, but contrived, in the midst of his toils and cares, to educate them thoroughly; and, in fact, they never had any other teacher. Much of his time was employed in writing for periodical publications. For several years he was an occasional contributor to the Edinburgh Review, which is indebted to his pen for some very able articles. He also wrote in many other periodical publications, among which were the British, the Eclectic, and Monthly Reviews. One of the works to which he was a large contributor was the Philanthropist, a periodical journal established by the Quakers and other benevolent promoters of education, the reform of the criminal code, prison discipline, &c. With these excellent persons Mr Mill actively co-operated in the exertions to which the Lancasterian schools, and Infant schools, owed their origin; and, at a later period, he was one of the founders of the London University.

His principal work, the History of British India, had been commenced as far back as the year 1806. His venturing even to think of so great an undertaking, whilst

¹ We ought here to add, that Sir John Stuart continued till his death (about 1820), to correspond with Mr Mill, and to take the most friendly interest in him, and was the only person of station from whom, in his arduous struggles, he ever received the smallest help or encouragement.

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writing for his daily bread, and burdened with the maintenance and domestic education of a numerous family, furnishes one of the noblest proofs of intellectual ardour, and confidence in the resources of industry, that can be found in the whole history of literature. Nor were his labours confined to this work, and the other daily calls we have mentioned; for he found time, besides, to write more than one pamphlet upon subjects of interest at the moment; particularly a very conclusive answer to Mr Spence's celebrated tract, entitled *Britain independent of Commerce*. The answer was published in 1808. His steady industry brought him at last in sight of the goal of which he never lost sight, though sometimes almost sinking under the toils which the pursuit had imposed upon him, we mean, the completion of his *History*. In a letter written in October 1816, he thus expresses himself:—"Thank God, after nearly ten years since its commencement, I am now revising it for the press. Whatever else it may contain, it will at least contain the fruits of a quantity of labour, of which nobody who shall not go over the same ground, and go over it without the assistance of my work, can form an adequate conception. Had I foreseen that it would have been one half, or one third, of what it has been, never should I have been the author of a *History of India*." It was at last published in five volumes octavo, in the winter of 1817-18. It is the smallest merit of this book, that it was, and still is, the only single work calculated to convey to the general reader any intelligible notion whatever of India, or Indian affairs as a whole, and which is therefore indispensable to all Englishmen who would possess even the most general knowledge of one great department of their country's interest. This is much; but it achieved far more. We are only saying what will be confirmed by the most eminent of those who have administered Indian affairs for the last ten years, when we say, that Mr Mill's work was the beginning of sound thinking on the subject of India. It gave a new turn to the thoughts of all the most thinking men amongst those who filled the most important posts in the local administration of India; and the measures of government in that country have for many years borne, and are every year bearing, more and more the impress of his views.

Although he had very freely censured the conduct of the East India Company, yet the powers of mind and knowledge of the subject which he displayed induced the Court of Directors, in the spring of 1819, when they were desirous of strengthening their home establishment, to introduce him into it (though personally unknown to most of them, and having little or no interest), and to intrust to him the chief conduct of their correspondence with India, in the revenue branch of administration. This is one of the most remarkable, as well as honourable instances of success in life, ever achieved by any literary man. Mr Mill had the rare fortune of being not only the first person who showed how India ought to be governed, but of being called upon to be a leading instrument in executing his own views. And not only in that situation, but in the higher one to which he rose in the course of promotion, viz. head of the department of correspondence with India in the India House, or, in other words, chief minister for Indian affairs to the East India Company, he lived to see almost all the great principles which he had advocated not merely recognised, but a commencement made in carrying them into practice in the government of India.

Mr Mill's official duties might well have furnished him with an excuse for relinquishing his pen as an author. But his mind was not of a cast to stop short in the career of inquiry, or to allow the calls of business to suppress the fruits of his reflections. It was observed of Lord Brougham, by the late Sir Samuel Romilly, that he could find time for every thing. So was it with Mr Mill. Never

behind in his official duties, and mixing largely in the society of intelligent men, he was all the while engaged, just as if his daily bread yet depended on the employment of his pen, in literary labour. To this noble ardour the present work is much indebted. He became a contributor to the *Supplement* to its former editions, about three years before his appointment to the India House; but his contributions were continued nearly till the completion of that work in the year 1824; and he never sought an excuse, in his official labours, for any refusal to write what he thought might be useful. The extensive circulation of the work made it, in his eyes, a precious instrument for the diffusion of knowledge; and on this, and other accounts, he always took a strong interest in its character and success. Without enumerating the whole, we may mention the articles on Colonies, Education, Government, Jurisprudence, Law of Nations, Liberty of the Press, and Prison Discipline, as the most remarkable. These essays, all of which are incorporated in the present edition, were so widely disseminated by means of the work in which they appeared, and by separate republications of them, at a very cheap rate, as to make them by much the best known of his productions; and, we believe we may add, the most effective in stirring the thoughts of his contemporaries.

In 1821-22 he published his *Elements of Political Economy*, a treatise in which the science, as remodelled by Ricardo, was for the first time brought into a systematic and logically arranged form. In some of the criticisms on this work it seems to have been forgotten, that here Mr Mill made no pretensions to originality; that he "professed," to borrow his own words, "to have made no discovery;" his object having been simply "to compose a school-book of political economy."

Mr Mill's ingenuity as a very acute and original metaphysician was abundantly displayed in his *Analysis of the Phenomena of the Human Mind*, published in 1829. In this work he evinced analytical powers rarely, if ever, surpassed; and which have placed him high in the list of those subtle inquirers who have attempted to resolve all the powers of the mind into a very small number of simple elements. Mr Mill took up this analysis where Hartley had left it, and applied the same method to the more complex phenomena, which the latter did not attempt to explain. From the general neglect of metaphysical studies in the present age, this work, which, at some periods of our history, would have placed its author on a level, in point of reputation, with the highest names in the republic of letters, has been less read and appreciated than any of his other writings.

Mr Mill's last work was the *Fragment on Mackintosh*, published anonymously in 1835, but of the authorship of which he made no secret. This is a criticism of a very severe kind, upon the *Dissertation on the History of Ethical Philosophy*, contributed by Sir James Mackintosh to the present publication. Most even of those who agree in the general opinions expressed by Mr Mill, have admitted, that the degree of bitterness which he manifested towards this eminent and singularly candid writer was altogether uncalled for. With all our strong respect for his abilities and character, we confess that we never could look into this publication without feelings of wonder and mortification, that Philosophy sometimes can leave her votaries so bereft of sentiments which, in their cool moments, they never fail to inculcate as constituting the primary conditions of all true, manly, and useful inquiry. But no one can doubt Mr Mill's sincerity, nor question the attention due to any thing which proceeded from his pen on the subjects adverted to in the *Fragment*.

Mr Mill wrote several of the principal articles in the early numbers of the *Westminster Review*, and resumed the pen, after an interval of some years, to write the cele-

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Mill. brated article on the Ballot. After the junction of the Westminster with the London Review, he wrote some other articles for that journal, which, though rougher, are perhaps more racy and characteristic than his earlier contributions. The last of them, entitled *Aristocracy*, was the last of his literary labours. It was written during the illness of which he died.

Before taking leave of the writings of this remarkable man, we ought perhaps to mention, as descriptive of his mental character and pursuits, that he had at one time resolved, after finishing his *History of India*, to write a *History of English Law*. He speaks as follows of this project, in a letter written in 1818:—"You do not know, perhaps, what is my presumption on the subject of law. The next work (after the *History*) which I meditate, is a *History of English Law*, in which I propose to trace, as far as possible, the expedients of the several ages to the state of the human mind, and the circumstances of society in those ages, and to show their concord or discord with the standard of perfection; and I am not without hopes of producing a book readable by all, and if so, a book capable of teaching law to all." We do not know whether he ever made any progress in the execution of this design, or by what circumstances he was induced to abandon it. His intimacy with Mr Ricardo, and his strong bias towards metaphysical speculations, probably induced him to endeavour, in preference, to systematize the science of political economy, and to prosecute the inquiries which led to the publication of his *Analysis of the Phenomena of the Mind*.

Mr Mill, from an early age, was subject to gout; a disease which not unfrequently in old age affects the chest. For some winters previously to his death he had an obstinate cough, which, however, went off as the summer advanced. But in the summer of 1835 it did not go off, and the symptoms of pulmonary consumption by degrees manifested themselves. He declined slowly, and died on the 23d of June 1836. His remains were buried in Kensington Church, having lived at Kensington during the last five years of his life.

If we were called upon to state what, beyond all others, was the distinguishing characteristic of Mr Mill's mind, we should answer, his power of generalization. To have this power in a high degree, three qualities of mind, each of them rarely to be met with in a high degree separately, still more rarely together, are requisite—the observing faculty, the analytical faculty, and the ratiocinative faculty. Thus, in Aristotle the observing and ratiocinative powers, and in Bentham the ratiocinative, existed in considerable force, whilst the former had but little, and the latter still less, of the analytical. They made enumerations and catalogues with wonderful minuteness, which, however, from want of analysis, were often inaccurate or imperfect; rendering, moreover, the question treated unnecessarily complicated, in proportion to that imperfection. The very complication in which a patient but unanalytical mind is sure to involve any large subject, frequently obtains for such men the character of possessing and displaying a vast knowledge of and command over details, when in truth the display and enumeration of endless details arises from their inability to penetrate into the heart of their subject,—to take it to pieces, and then separate from it what is extrinsic, bringing out the real core of the question into naked and broad light. He who can do this will generalize accurately. But to do this is given to few; whilst, on the other hand, to generalize inaccurately, requires neither labour in collecting facts, nor penetration in analysing them, nor logic in treating the results of the analysis; and is unfortunately one of the commonest of the qualities that belong to men. And, as the mass of mankind seldom give themselves the trouble to

seize distinctions, they are in the habit of applying to generalization, in the true sense of the word, and as Mr Mill possessed it, the censure deserved only by such slovenly generalizations as those which commonly pass under the name. Of the three faculties necessary for correct generalization, Mr Mill had the observing faculty in a smaller proportion than the other two; but it would be difficult to name any writer who possessed a larger share of all the three together.

Mr Mill was wont to attribute a considerable share of influence in the formation of his intellectual character to his reading the works of Plato. And, no doubt, to read with understanding the writings of Plato, must produce extraordinary effects upon the mind of any man. In the style, however, in which Mr Mill developed and embodied his speculations, he bears more resemblance to Aristotle than to Plato. At the same time, this was rather in the form than the matter; for he had little of Aristotle's vast power of observation, and he had much of Plato's dialectical and analytical powers, though altogether wanting the poetical qualities of his mind. Of modern philosophers, he whom Mr Mill most resembles is Hobbes. There is in both the same clearness, the same condensation, the same simplicity of style, the same utter abjuration of all rhetorical ornament, or any thing else that might lead either the mind of the writer or of the reader away, even for a moment, from the point under discussion. There is often, however, a quiet dry humour lurking in Hobbes's sentences, which is not to be found in Mr Mill's. Hobbes's language, too, is more idiomatic. In the boldness and originality of the tone of thought the resemblance is striking.

It has been usual with certain persons to consider Mr Mill as a disciple of Bentham. It seems worth while to say a few words on this point. Mr Mill, in his *Fragment on Mackintosh*, having occasion to state that no man ever derived his opinions from the conversation of Mr Bentham, inasmuch as, with him, conversation was relaxation purely, adds, "It is also a matter of fact, that till within a few years of the death of Mr Bentham, the men of any pretension to letters who shared his intimacy, and saw enough of him to have the opportunity of learning much from his life, were in number two. These men were familiar with the writings of Mr Bentham; one of them, at least (Mr Mill himself), before he was acquainted with his person. And they were neither of them men who took any body for a master, though they were drawn to Mr Bentham by the sympathy of common opinions, and by the respect due to a man who had done more than any body else to illustrate and recommend doctrines which they deemed of first-rate importance to the happiness of mankind." So far, and no farther, was Mr Mill a disciple of Mr Bentham.

A trait of Mr Mill's character which well deserves to be commemorated, was the warm interest he always took in the intellectual progress of any young man known to him as possessing some capacity and inclination to improve himself. His enlarged and philosophical view of the subject of education leading him to regard nearly the whole of man's life as a course of education, he endeavoured, with great earnestness and energy, to impress upon the minds of such young men the importance of educating themselves after a different standard from the vulgar one of their age; and of rendering even those studies which their various professions or modes of life obliged them to pursue, as much as possible the means of invigorating and improving their intellectual and moral nature. In enforcing his precepts, Mr Mill was aided by the extraordinary nerve and clearness with which he expressed himself in conversation. He was, indeed, one of the best discourses, on grave subjects, that we ever met with; and he spoke with an amenity and ease, and even with a degree of point and anima-

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tion, that could not have been anticipated from acquaintance merely with the dry and emotionless character of his written productions.

In a word, the tendency of all Mr Mill's writings was to lead men to trust for their opinions neither to the authority of a name, however renowned, nor to the dogmatical assertions of a man or a body of men, however powerful; but to the evidence of their senses and their reason. To do this he deemed of first-rate importance to produce good morals, good legislation, good government, in a word, human happiness; and he enforced his precepts with an earnestness proportionate to so momentous an end. In like manner, he regarded all attempts to corrupt the springs of government, and thereby to "strike at the well-being" to use his own words, "of all the myriads of whom the great body of the community is composed, from generation to generation," with a severity of indignation that might be expected from his earnest and energetic character. His comprehensive mind, long habituated to large views, and to dealing with classes rather than individuals, sympathized as keenly with the bulk of mankind as an ordinary mind does with the hero or heroine of a well-told tale. Such ought to be, but how seldom has it been, the character of the legislator and the statesman:

patriæ impendere vitam,
Non sibi, sed toti genitum se credere mundo.

MILL, *John*, a very learned divine, was born at Shap in Westmoreland, about the year 1645, and became a servitor of Queen's College, Oxford. Upon his entering into orders he became an eminent preacher, and was made prebendary of Exeter. In 1681 he was created doctor of divinity; about the same time he was made chaplain in ordinary to King Charles II.; and in 1685 he was elected principal to St Edmund's Hall in Oxford. His edition of the Greek Testament, which will render his name ever memorable, was published about a fortnight before his death, which happened in June 1707. Dr Mill was during thirty years employed in preparing this edition.

MILLAR, JAMES, M.D., whose name is well entitled to notice here, on account of his connection with this work, was born in the town of Ayr, on the 4th of February 1762. He received the early part of his education in the Academy at Ayr, where he acquired considerable knowledge of the learned languages. He afterwards passed through the ordinary *curriculum* of the literary, philosophical, and theological classes in the university of Glasgow, in order to qualify himself to enter the church of Scotland; and, as is usual for young men destined to that profession, employed part of his time in the business of private teaching. Having been induced by his friend Dr Porteous to go out to Jamaica as tutor in a gentleman's family, he remained in that island for four years; and upon returning home, he was licensed to preach by the presbytery of Irvine. He afterwards for a considerable time officiated as chaplain to the university of Glasgow. His success in this vocation did not, however, correspond with his expectations; and, being naturally possessed of an acute and aspiring mind, he turned his thoughts to the study of medicine. He accordingly removed to Edinburgh, and completed his medical course in this university, where he received his degree. He then proceeded to Paisley, and continued to exercise the duties of his profession for some years in that place; but as he had always been distinguished by an ardent love of science, he was induced to return to Edinburgh, as likely to furnish occupation more congenial to his taste and views. He was at first engaged in writing for, or in superintending, one or other of the periodical miscellanies then published in this city; but a more extensive and important field was at length opened to his abilities and industry, by the proprietors of this Encyclopædia, with whom he entered into an agreement to superintend a new and

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improved edition of it, being the fourth. The third edition consisted of eighteen volumes, to which was appended a Supplement in two; but it was resolved, from the first, to extend the fourth to twenty volumes, and Dr Millar had the satisfaction of conducting this great undertaking from first to last, and of being instrumental in introducing into the work, notwithstanding the limited means at his disposal, a variety of new treatises, besides other improvements, not less required though not so prominent, and many corrections. Having abandoned all other occupations, in order to devote himself exclusively to this work, he took possession of the editorial house, connected with the printing establishment belonging to the proprietors, and there he continued to reside till the completion of the undertaking. This was the happiest as well as the most useful period of his life. The house he occupied was small but comfortable; and it contained a very useful collection of books of reference and general literature, to which the proprietors continued to add from time to time; so that he was not only enabled to furnish his contributors with the materials of their labours, but to carry on his own, without stirring abroad in quest of the necessary books. As chemistry and natural history were the sciences which he chiefly studied, and to which, indeed, he was enthusiastically devoted, the new articles which he himself contributed to the work have been mostly superseded, and replaced by others more in unison with the rapid progress of knowledge in these departments; but it is due to his memory to mention the following, as affording proofs both of his industry and the range of his acquirements: Cetology, Chemistry, Conchology, Crystallization, Dyeing, Dynamics, Erpetology, Furnace, Galvanism, Mineralogy, Ores, and the analysis of Stones. Some of these treatises were afterwards republished, we believe, in separate forms. About the same period that he completed his labours upon the Encyclopædia, namely, in 1810, he gave to the world a new and greatly improved edition of Williams's Mineral Kingdom, in two volumes octavo. Although entirely a work of practical experience, the result of a confined occupation in the coal and mining districts of the country, Dr Millar so enlarged and expanded it, as to render it a not unacceptable present to the scientific reader. In an appendix, he gave an extended view of the sciences of mineralogy and geology, which was necessarily precluded by the limited knowledge and experience of Mr Williams. Although geology since that period has made singular and unexpected advances, this part of the publication deserves to be noticed, as including a more copious detail of geological facts than had at that time been presented to the public.

The only other literary undertaking in which Dr Millar engaged was the Encyclopædia Edinensis, the ostensible design of which was to present to the public, in a few volumes, a succinct and accessible epitome of general knowledge, suited to the great mass of the community. But in consequence of the embarrassed affairs of the proprietors, the undertaking was for a time suspended, and he did not live to complete it. From this period Dr Millar relinquished all connection with literary undertakings, and officiated for several years as physician to the Edinburgh Dispensary, the duties of which situation he discharged with a zeal and philanthropy beyond all praise. By those who knew him well Dr Millar was greatly esteemed. He was an agreeable and intelligent companion, whose conversation was acceptable as well to men of the world as to men of science. Though he lived a life of labour, his rewards were but small; and this, joined to the failure of some of his attempts to establish himself as a lecturer on chemistry and mineralogy, contributed somewhat, in the later period of his life, to sour his temper; but he always manifested a liberal and independent spirit, and took

Millstone a warm interest in the progress of knowledge, as well as in the welfare of its cultivators. He died at Edinburgh on the 13th of July 1827, leaving a widow and several children.

Millener.

MILLSTONE, the stone by which corn is ground.

The millstones which we find preserved from ancient times are all small, and very different from those which are now in use. Thoresby mentions two or three such found in England, amongst other Roman antiquities, which were but twenty inches broad; and there is reason to believe that the Romans, as well as the Egyptians and Jews, did not employ horses, or wind, or water, as we do, to turn their mills, but made their slaves and captives of war do this laborious work. Sampson, when a prisoner to the Philistines, was treated no better, but condemned to turn the millstone in his prison. The runner or loose millstone, in this sort of grinding, was usually heavy for its size, being as thick as it was broad. This is the millstone which is expressly prohibited in Scripture to take in pledge, because, lying loose, it was more easily removed. The Talmudists relate, that the Chaldeans made the young men of the captivity carry millstones with them to Babylon; and hence, probably, their paraphrase renders the text "have borne the mills or millstones," which might thus be true in a literal sense. They have also a proverbial expression of a man with a millstone about his neck; which they use to express a man under the severest weight of affliction. This also plainly refers to the same small kind of stones.

MILLENARIANS, or **CHILIASTS**, a name given to those in the primitive ages, who believed that the saints will reign with Christ on earth for a thousand years. See **MILLENNIUM**.

MILLENER, or **MILLINER**, one who sells ribands and dresses, particularly head-dresses for women, and who makes up those dresses. Of this word different etymologies have been given. It is not derived from the French, who cannot express the notion of *milliner* otherwise than by the circumlocution *marchande* or *marchande des modes*. Neither is it derived from the low Dutch, the great but neglected magazine of the Anglo-Saxon. For Sewel, in his English and Dutch Dictionary, published in 1708, describes *millener* as a "pedlar who sells ribands and other trimmings or ornaments, a French pedlar." Littleton, in his English and Latin Dictionary, published 1677, defines *millener*, "a jack of all trades," *millenarius*, or *mille mercium venditor*; that is, "one who sells a thousand different sorts of things." From this etymology, which seems fanciful, we must hold, that it then implied what is now termed "a haberdasher of small wares." Before Littleton's time, however, a somewhat nicer characteristic than seems compatible with this notion, appears to have belonged to them; for Shakspeare, in his Henry IV. makes Hotspur, when complaining of the daintiness of a courtier, say, "he was *perfumed* like a milliner." The fact seems to be, that there were milleners of several kinds; as, *horse milleners*, who make ornaments of coloured worsted for horses; haberdashers of small wares, the *milleners* of Littleton; and *milleners* such as those now peculiarly known by that name, whether male or female, to whom Shakspeare's allusion seems most appropriate. Lastly, Dr Johnson, in his dictionary, derives the word from *milaner*, an inhabitant of *Milan*, whence first came people of this profession, as a *Lombard* is a banker.

MILLE PASSUS, or *Millia Passuum*, a very common expression amongst the ancient Romans for a measure of distance, commonly called a *mile*. *Milliarium*, rarely used. A Roman mile Hesychius made to consist of seven stadia; Plutarch, little short of eight; many others, as Strabo and Polybius, eight stadia and no more. The reason of this difference seems to be, that the former had a regard to the Grecian foot, which is greater than the Roman or Italic. This distance is oftentimes called *lapis*, from the stone by which it was marked or indicated.

MILLENNIUM, a period of a thousand years; generally used with reference to the thousand years during which, according to the statement of the Apostle John in the 4th verse of the twentieth chapter of the Apocalypse, Christ is to reign with his saints upon earth.

As almost all nations are possessed of some traditionary information respecting the existence of a happy and a holy age at the commencement of the world's history, so among most of them do we find traces, more or less distinct, of an expectation that a period of still greater excellence will immediately precede its close. In several of the oriental religious systems this expectation occupies a prominent place;¹ nor will the classical reader need to be reminded of the well-known Eclogue of Virgil, in which he describes the glories of "the last age," and the return of the Saturnian reign, in strains which so strikingly accord with those of the Jewish Scriptures, that this poem seems to have been commonly regarded by the early church as prophetic of the birth and reign of Christ.² A still more remarkable, because more explicit, allusion to a millennium, occurs in the writings of Plato, in the statement which he repeatedly makes, that a period of a thousand years (*χιλίας πορεία, χίλιοστον έτος, περιόδος χίλιετης*) must intervene between death and our "arrival at the inheritance and possession of the second life."³

Among the Jews this expectation assumed a more definite form, and was expressed in less hesitating language. Their prophets distinctly revealed to them the certainty of a period of future felicity under the reign of the Messiah;⁴ and they had, from a comparatively early age, the tradition, that that period would extend through a thousand years. This tradition seems to have had its rise in the notion, that as the work of creation was divided among six ordinary days, so the world would have to pass through six divine days of toil and suffering (each of which days they imagined to be a millennium, from a misinterpretation of Ps. xc. 4); and that as God rested on the seventh day, so should the seventh millennium be a period of universal rest and quiet under the reign of the Messiah. In the rabbinical writings, frequent allusions to this opinion are to be found, the most important of which have been collected by Wetstein, in his notes on Apoc. xx. Of these allusions, the following may be taken as a specimen: "There is a tradition in the house of Elias, that the righteous whom the holy blessed God shall raise from the dead, shall not return again to the dust, but for the space of *a thousand years*, in which the holy blessed God shall renew the world, they shall have wings like the wings of eagles, and shall fly above the waters."⁵

From the Jews, this notion of a personal reign of the Messiah with his saints on earth, was adopted by several in the early church, by whom the passage in the Apocalypse above referred to was confidently quoted in support of the opinion. By some of these the blessings

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See Plutarch *De Isid. et Osir.* c. 47; Hyde *De Relig. Vet. Pers.* p. 832.

² See Augustine, *Inchoat. Expos. in Ep. ad Romanos*; Lactantius, *Instit.* vii. 24; Eusebius, *Constantini Orat. ad Sanctorum Cat.* c. 19.

³ *Timæus*, p. 1054, E.; see also *Phæd.* p. 1223, D.; and *De Rep.* lib. x. p. 761, E.

⁴ See, among other passages, Is. ii. 1-4, ix. xi. xxv.; Zech. xiv.

⁵ Sanhedrin, fol. 92, quoted in Dr Ad. Clarke's *Comment. in loc.*

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anticipated during the millennium were regarded as entirely of a temporal and sensual kind, while others looked forward to that period as a season of spiritual enjoyment and religious harmony. In neither of these forms, however, does the opinion ever seem to have become general in the church. Indeed we are expressly informed by Origen, that it was confined to those "of the simpler sort," and to such as, "refusing the labour of intelligence, followed the superficial mode of literal interpretation."¹ Great obscurity, however, attends the history of this dogma in the early church, as the documents we possess are too few, and too partial in their information, to justify our expressing any definite opinion on the subject. From the testimony of Eusebius, we learn that the first who taught it in the church was Papias, a bishop of Phrygia, in the earlier part of the second century, who professed to have received a traditional revelation on the subject from the apostles. Influenced by a regard to the piety and antiquity of the man (*την ἀρχαιοτητα τῶνδρος προβεβλημένοι*), several ecclesiastics, and among the rest Irenæus and Justin Martyr, adopted his opinion. Adherents were also found in the Latin church, especially from among the Montanist party. It is justly remarked, however, by Professor Neander, that the defensive attitude which the advocates of the doctrine perpetually assume in regard to it, affords a strong presumption that it was not the doctrine of the church in general.²

In the third century it was vehemently assailed by Origen, and as eagerly defended by Nepos, a bishop of the district of Arsinoe, in Egypt. The latter, however, was but a feeble antagonist for so redoubtable a controversialist as Origen, whom his scholars delighted to style the Adamantine; and consequently his interference served only to quicken the downfall of the cause he had espoused. The assault of Origen was followed by that of Dionysius, bishop of Alexandria, and one of Origen's most able scholars, which seems, in the Eastern church at least, completely to have driven the opinion into obscurity.³ From this time forward we find no traces of it in ecclesiastical history, until we arrive at the tenth century, when it was revived, though in a very altered form, and used for the purpose of terrifying the ignorant populace into larger concessions to the ambition and avarice of the papal power. They were taught that the millennium, during which Satan was to be bound, was to be calculated from the birth of Christ, and consequently was then rapidly drawing to a close; that at its termination Satan would be again set free, and the reign of Anti-Christ would commence; and that, after a short season of triumph to the enemies of the church, the last judgment would take place, and the world be consumed by the final conflagration. So powerful was the effect produced by the teaching of this doctrine, that multitudes, as the eventful year that was to close the last century of the millennium approached, forsook their homes, "and hastened to the shores of Palestine, with the pious persuasion that Mount Sion would be the throne of Christ when he should descend to judge the world; and these, in order to secure a more partial sentence from the God of mercy and charity, usually made over their property before they departed, to some adjacent church or monastery."⁴ The much-dreaded year, however, having passed away, without any of the expected convulsions,

the minds of the people recovered their equilibrium. Those who had fled returned to their homes, and resumed their wonted occupations; "and the only lasting effect of this stupendous panic was the augmentation of the temporal prosperity of the church."⁵

Since the reformation, the opinion of the early Millenarians has been revived in the church; and the doctrine of a personal reign of Christ on earth with his saints has been maintained by many excellent persons, as one of the truths clearly revealed in the Scriptures. The tenets of those who avow this opinion are chiefly the following:—That Jerusalem is to be rebuilt, the temple restored, and sacrifice again offered on the altar; that this city is to form the residence of Christ, who is to reign there in glory with all his saints for a thousand years; that for this purpose there shall be a resurrection of all the pious dead, that none of the Saviour's followers may be absent during his triumph; that at the close of the thousand years, they shall all return to heaven, and the world be left to Satan and his followers for a season; and that then the general resurrection and last judgment shall take place, and the history of the world be brought to a close. In support of these tenets, they appeal to numerous passages in the prophetic writings of the Old Testament, to some sayings of Christ himself recorded in the Evangelists, to one or two detached passages in the writings of the apostles, and principally to the declarations of St John in the Apocalypse. The passages in the Prophecies on which most stress is laid by them, are those in which the latter-day glory seems to be described in connection with the return of the Lord of Hosts unto Zion, the establishment of his sanctuary with men for ever, and the coming of the nations to Jerusalem to receive instruction, and offer their homage to him.⁶ The declarations of our Lord referred to are those in which he speaks of the destruction of Jerusalem in connection with his second advent;⁷ from which it is inferred that Jerusalem shall remain in its present state, and that seasons of tribulation and sorrow shall befall the church, until Christ come to restore the one to its former glory, and to exalt the other over all its enemies.⁸ The passages quoted from the apostles are chiefly two: the one the address of St Peter to the Jews,—“Repent and be converted, that your sins may be blotted out, when the times of refreshing shall come from the presence of the Lord; when he shall send Jesus Christ, which before was preached unto you;”⁹ which is held to prove that Christ shall come again, and that this event shall be attended with times of refreshing to the Jews; the other the declaration of St Paul to the Thessalonians,¹⁰ that “the dead in Christ shall rise first;” from which it is inferred that there will be a resurrection of the just antecedent to the general resurrection. The main prop of the doctrine, however, is the passage in the twentieth chapter of the Apocalypse, already referred to, and which is as follows: “And I saw thrones, and they sat on them, and judgment was given unto them; and I saw the souls of them that were beheaded for the witness of Jesus, and for the word of God, and which had not worshipped the beast, neither his image, neither had received his mark upon their foreheads or in their hands; and they lived and reigned with Christ a thousand years. But the rest of the dead lived not again till the thousand years were finished. This is

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¹ *Proleg. in Cant. cant.* 69, B.; *de Princip.* ii. 11, sect. 2.

² *Kirchengeschichte*, bd. i. abt. 3, p. 728; see also Waddington's Church History, ch. iii.; Whitby's Treatise on the Millennium, appended to his Commentary, &c.

³ *Euseb. Hist. Eccl.* vii. 24, 25.

⁴ Waddington's Church History, chap. xv.

⁵ *Ibid.*

⁶ See Begg's Connected View of some of the Scriptural Evidence of the Redeemer's Speedy Personal Return, &c. pp. 85-118.

⁷ *Matt.* xxiv.; *Mark.* xiii.; *Luke.* xxi.

⁸ Begg's Letters on our Saviour's Predictions, &c. *passim*.

⁹ *Acts.* iii. 19, 20.

¹⁰ *1 Ep.* iv. 16.

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the first resurrection." Verses 4, 5. Here it is contended that we have a distinct testimony in favour of a millennial reign of Christ and his people, and of a resurrection of those who had been faithful to him, as well as of those who had suffered for his sake, antecedent to that of the rest of the dead, and hence called "the first resurrection."

By those who oppose this system, it is generally admitted that the expectation of a long season of uninterrupted triumph to the cause of Christ, is one which is fully authorized by the declarations of Scripture. It is denied, however, that these declarations, when properly interpreted, support the notion of a personal reign, and a twofold resurrection. With regard to the passages from the Old Testament prophecies, it is maintained, that many of those adduced by Millennarians, as favouring their system, have been already fulfilled in the temporal history of the Jewish nation, and that in others which seem to have a still future reference, Jerusalem is used as typically representative of the Christian church in its triumphant state; the temple is spoken of in reference to the ministrations of the Gospel; and the coming of the people to Jerusalem is set forth as indicative of the universal prevalence of the Christian faith. The inference deduced by Millennarians from the words of our Lord above referred to, is regarded by their opponents as at best very obscure and far-fetched, while, on the other hand, it is contended, that the obvious comparison which our Lord draws between the destruction of Jerusalem and his second coming, as well as the circumstances of appalling and unexpected suddenness with which his appearance will be made, seem much better to accord with the notion, that the coming spoken of is his coming to judgment, than with the opinion that it is an advent for which his church shall be longing, and the world prepared. In the statement of St Peter to the Jews, it is admitted that there are some expressions which would seem at first sight to favour the millennialian scheme; but it is argued that every such inference is precluded by the words which follow, and in which the apostle declares, that the heavens must retain Christ "until the restitution (or accomplishment) of all things, which God hath spoken by the mouth of all his holy prophets since the world began." As, therefore, by the showing of Millennarians themselves, the glories of the millennium form part of the "all things" that are revealed in inspired prophecy, and which must be fulfilled *before* Christ shall re-appear on earth, it is plainly impossible that he can come to our world in person at the *commencement* of that period; and consequently the times of refreshing spoken of by St Peter must be interpreted of other blessings than those which would flow from the personal reign of Christ at Jerusalem. As to the statement of St Paul, that "the dead in Christ shall rise first," it is affirmed that a single glance at the context is sufficient to convince us that the apostle is not establishing a difference between the righteous and the wicked as to the time of their respective resurrections; but is simply showing that those believers who are alive at the season of Christ's second advent shall not enjoy any advantage over those who are dead, for the latter shall be raised first, *i. e.* previous to the common ascent of the whole to meet the Lord in the air. In reference to the passage from the Apocalypse, it is contended, *1st*, That the expression "*first* resurrection" no more necessitates a twofold *corporeal* resurrection, than the phrases "first and second death," so frequently employed by the same writer, necessitate the supposition of a twofold corporeal dissolution; but that in both cases we have an instance of the same intermingling of the spiritual with the material, as in our Lord's declaration, "Let the dead bury their dead," where, as is generally admitted, the first adjective is used in a spiritual or metaphorical, the second in a literal and corporeal sense: *2dly*, That the phrase, "the

rest of the dead," refers to "the remnant" spoken of in the 21st verse of the 19th chapter (the words in the original are the same in both verses, *οι λοιποι*), by whose resurrection is intended the temporary restoration of the reign of evil after the millennium: *3dly*, That it is not a legitimate interpretation to regard the expression, "I saw the *souls* of them that were beheaded," &c. as intimating their *corporeal* resuscitation; for though we may properly enough speak of a *soul* when we mean a *person*, yet it would outrage all propriety of language for any one to say that he saw the *souls* of certain individuals, when he meant that he saw these individuals themselves: *4thly*, That by the return to the earth of the souls of the martyrs and confessors, nothing more is intimated than the universal prevalence of that holy and determined spirit by which they were distinguished; in the same way as the ancient prophecy, that Elias should return to earth before the appearance of the Messiah, is allowed to have received its accomplishment when John the Baptist came "in the *spirit* and *power* of Elias:" *5thly*, That it is as contrary to sound principles of interpretation to expound a book professedly symbolical literally, as it would be to expound a professed narrative symbolically: *6thly*, That it is imperative on those who insist on the literal interpretation of this passage to be consistent, and interpret literally the whole book, in which case we should have literal vials, and trumpets, and mill-stones, and chains, and burning lakes, &c.; an extent of literality for which few will be hardy enough to contend: and, *lastly*, That by interpreting the whole passage symbolically, and understanding by it a prediction of a season of joyful triumph to the church, during which the whole world shall be under the religion of Christ, and the zeal and piety of its holiest members in its purest days shall be universally diffused, no violence is done to any part of it, while a meaning is elicited in entire accordance with the general tenor of Scripture.

It is further objected by those who are opposed to Millennarianism, in the *first* place, that the hypothesis is in itself exceedingly improbable; for since Scripture assures us that the departed saints are already with Christ in heaven, in the enjoyment of unspeakable felicity, it is hardly conceivable that they would leave such a state to dwell for a thousand years on earth, in a state which at best must be one of imperfect enjoyment, and then return to heaven to permit their enemies for a season to reign in their stead: *2dly*, That the millennialian notion of a resurrection of the righteous, antecedent to that of the wicked, is directly opposed to the testimony of Scripture, which represents the two as simultaneous; see, *e. g.* John v. 28-29, &c.: *3dly*, That the idea of a long interval elapsing between the advent of Christ and the last judgment, is inconsistent with those passages which represent the one as immediately consequent upon the other; such as, 2 Thess. i. 7-10; 2 Tim. iv. 1, &c.: *4thly*, That, on the millennialian hypothesis, there can be no judgment of the righteous whatever, for they having been once admitted to *reign* with Christ, can never after that be placed for trial at his bar,—a hypothesis clearly at variance with innumerable passages of Scripture, such, *e. g.* as Rom. xiv. 10-12; Math. xxv. 31-46, &c.: *5thly*, That to represent the millennium as a state of immortality on earth, is to confound it with the New Jerusalem, though the two are distinctly revealed as separate states, the one previous and the other subsequent to the final judgment: and, *lastly*, That the theory of millennialianism is in two points at least self-contradictory; for it not only represents Christ as reigning until the *last* enemy has been destroyed, and yet supposes the existence of a whole host of enemies, who, at the close of that reign, are to be gathered together; but also represents them as contending with the saints, until they are consumed by fire from God (Rev. xx. 7-10), though,

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Milliarium Aureum. ^{||} Millot. according to another part of their hypothesis, the saints shall before this have returned with Christ to heaven. For these reasons, among others of less weight, this hypothesis of a personal reign of Christ on earth has been rejected by the majority of divines, and the period of the millennium regarded as a season of great spiritual blessedness, consequent on the complete triumph of Christianity throughout the earth. (N. N. N. N.)

MILLIARE, or MILLIARIUM. See MILLE PASSUS.

MILLIARIUM AUREUM, was a gilded pillar in the forum of Rome, at which all the highways of Italy met, as one common centre. From this pillar the miles were counted, and at the end of every mile a stone was put down. The military column was erected by Augustus Cæsar, and, as we are informed by travellers, is still to be seen.

MILLOT, CLAUDE-FRANÇOIS-XAVIER, a distinguished historian, was born in 1726 at Ornans, a small town of Franche-Comté, being descended from an old family connected with the profession of the law. When his studies were completed, he was admitted amongst the Jesuits; and after having taught classical learning in several towns, he was appointed professor of rhetoric in the College of Lyons, one of the most celebrated institutions of the society in France. In a discourse, crowned by the academy of Dijon, he ventured to pronounce an eulogium on Montesquieu, an act of boldness which offended his superiors, and, from the disagreements that ensued, led to his return to the world. The Abbé Millot, who was often successful in academical competitions, fancied that his talents fitted him to excel in the pulpit; but after having preached, without success, an advent at Versailles, and a lent at Lunéville, he abandoned a career for which he was disqualified by the weakness of his voice and the timidity and embarrassment of his manner. The desire of being useful to young people had induced him to undertake translations; and it was with this view that he composed abridgements of the history of France and of England, two works which had great success. About this time the Marquis of Felino, minister of Parma, having established in that city a college for the education of the young nobility, appointed the Abbé Millot to the chair of history, on the recommendation of the Duke of Nivernais. He was stranger to the intrigues which agitated the court, and, for the benefit of his pupils, formed the plan of an abridgement of general history. Whilst he was occupied with this work, Felino was marked out by his enemies as an object of popular hatred, insulted in the streets of Parma, and menaced even at the gates of his own palace. From this moment the Abbé Millot refused to quit his patron. In vain was it represented to him that the affection he evinced for the unfortunate minister would cause him to lose his place. "My place," said he, "is with a virtuous man, my benefactor, who is persecuted; I shall not lose that at least." On the retirement of the Marquis of Felino, the Abbé Millot returned to France, where his courageous conduct was known, and had procured him many friends. The court of Versailles, in name of that of Parma, granted him a pension of four thousand francs; and, in 1778, he was appointed preceptor to the Duke d'Enghien, a situation for which he was indebted to the high opinion entertained of his character. He was about to reap the reward of his labour and pains, when he was seized with an illness, which soon carried him off in the fifty-ninth year of his age. He died on the 21st of March 1785, the same day on which, nine years afterwards, his august pupil was shot in the fosse of Vincennes. The Abbé Millot had been received into the French Academy in 1777, in the room of Gresset. His election, managed by the house of Noailles, was a transaction or compromise between the parties which then divided the academy. There was one of the members who qualified his suffrage by declaring that he grant-

ed it only upon the condition that the recipiendary should write a little better; and D'Alembert, to tranquillize the philosophers, who hesitated to support an abbé, said to them, "I assure you he has nothing of a priest but the habit." The Abbé Millot was a man of a cold and serious character; he had no love for society, seldom spoke in company, and avoided that egotism which is so tyrannical in conversation. Attentive to the discussions which were continually arising about him, he rarely took part in them; and contradiction never ruffled his temper. Grimm, who saw him often in the society of Paris, describes his appearance as melancholy and dejected. "Nevertheless," adds the baron, "he is one of the happiest beings I know, because he is moderate, content with his lot, and attached to his particular kind of life and labour." D'Alembert used to cite him as the man in whom he had found the fewest prejudices and the least pretensions. The following is a complete list of his works, viz. 1. *Deux Discours*, one to prove that true happiness consists in making men happy, and the other, that hope is a good of which we do not sufficiently estimate the value, Lyons, 1750, in 8vo; 2. *Discours Académiques*, ibid. 1760, in 12mo; 3. *Discours sur le Patriotisme Français*, ibid. 1762, in 8vo; 4. *Discours de Réception*, Paris, 1768 and 1778, in 4to; 5. *Essai sur l'Homme*, translated from Pope with notes, and a discourse on English philosophy, Lyons, 1761, in small 12mo; 6. *Harangues d'Eschine et de Démosthène*, translated into French, Lyons, 1764, in 12mo; 7. *Harangues choisies des Historiens Latins*, ibid. 1764, in two volumes 12mo; 8. *Elémens de l'Histoire de la France*, Paris, 1769, in three volumes 12mo; 9. *Eléments de l'Histoire d'Angleterre*, Paris, 1769, in three volumes 12mo; 10. *Eléments d'Histoire Générale Ancienne et Moderne*, ibid. 1783, in nine volumes 12mo, a work which has been translated into the German, Danish, Dutch, English, Swedish, Italian, Spanish, and Portuguese languages; 11. *Histoire Littéraire des Troubadours*, Paris, 1774, in three volumes 12mo; 12. *Mémoires Politiques et Militaires pour servir à l'Histoire de Louis XIV. et de Louis XV.* ibid. 1777, in six volumes 12mo; 13. *Extraits de l'Histoire Ancienne, de l'Histoire Romaine, et de l'Histoire de France*, Paris, 1796, in 4to; 14. *Dialogues, et Vie du Duc de Bourgogne, père de Louis XV.* Besançon, 1816, in 8vo. Other works have been ascribed to Millot, but these are now known not to have been his. He was a member of the academies of Lyons, Nancy, and Châlons-sur-Marne; but that of Besançon neglected to adopt a man who did so much honour to the province, an omission which was repaired in 1814, by proposing as the subject of a prize an eulogium on Millot.

MILO, T. ANNIUS, a native of Lanuvium, who attempted to obtain the consulship at Rome by means of intrigue and seditious tumults. Clodius the tribune opposed his views; yet Milo would have succeeded but for an event which has given a collateral celebrity to his name. As he was going into the country, attended by his wife and a numerous retinue of gladiators and servants, he met on the Appian road his enemy Clodius, who was returning to Rome with three of his friends and some domestics completely armed. A quarrel arose between the servants; Milo supported his attendants, and the dispute became general; Clodius received many severe wounds, and was obliged to retire to a neighbouring cottage. Milo pursued his enemy in his retreat, and ordered his servants to despatch him. The body of the murdered tribune was carried to Rome, and exposed to public view. The enemies of Milo inveighed bitterly against the violence and barbarity with which the sacred person of a tribune had been treated. Cicero undertook the defence of Milo; but the continual clamours of the friends of Clodius, and the sight of an armed soldiery, which surrounded the judgment seat, so terrified the orator, that he forgot the greater part of

Milo his arguments, and the defence he made was weak and injudicious. **Milo** was condemned, and banished to Massilia. **Miltiades** Cicero soon afterwards sent his exiled friend a copy of the oration which he had prepared for his defence, in the form in which it now appears; and **Milo**, after having read it, exclaimed, "O Cicero, hadst thou spoken before my accusers in these terms, **Milo** would not now be eating figs at Marseilles." The friendship and cordiality of Cicero and **Milo** were the fruits of long intimacy and familiar intercourse. It was by the successful exertions of **Milo** that the orator was recalled from banishment, and restored to his friends.

MILO, or **MELOS**, an island of European Turkey, in the Archipelago. It is about sixty-six square miles in extent. It is mountainous and volcanic, and though in ancient times reported to have been populous, is now so unhealthy, that the population of less than 700 persons can only be kept up by annual emigrations from the Morea. The chief town of the same name is on the south part of the island, and is said once to have had 200 houses, but now has not so many inhabitants. Long. 24. 8. E. Lat. 36. 40.

MILTIADES, son of Cypselus, an Athenian captain, who obtained a victory in a chariot race at the Olympic games. He led a colony of Athenians to the Chersonesus. The causes of this appointment are striking and singular. The Thracian Dolonci, harassed by a long war with the Absynthians, were directed by the oracle of Delphi to take, for their king the first man they met in their return home, who should invite them to come under his roof and partake of his entertainments. This was **Miltiades**, who was very much struck at the appearance of the Dolonci, and with their strange arms and garments. He invited them to his house, and was made acquainted with the commands of the oracle. He obeyed; and when the oracle of Delphi had a second time approved the choice of the Dolonci, he departed for the Chersonesus, and was invested by the inhabitants with sovereign power. The first measures he took were to stop the further incursions of the Absynthians, by building a strong wall across the isthmus. When he had established himself at home, and fortified his dominions against foreign invasion, he turned his arms against Lampascus. But his expedition proved unsuccessful; he was taken in an ambuscade, and made prisoner. His friend Cræsus, king of Lydia, informed of his captivity, procured his release. He lived a few years after he had recovered his liberty. As he had no issue, he left his kingdom and possessions to Stefagoras the son of Cimon, who was his brother by the same mother. The memory of **Miltiades** was greatly honoured by the Dolonci, who regularly celebrated festivals and exhibited shows in commemoration of a man to whom they owed their greatness and preservation.

MILTIADES, the son of Cimon, and brother of Stefagoras mentioned in the preceding article, was, some time after the death of the latter, who died without issue, sent by the Athenians with one ship to take possession of the Chersonesus. On his arrival **Miltiades** appeared mournful, as if lamenting the recent death of his brother. The principal inhabitants of the country visited the new governor to condole with him; but their confidence in his sincerity proved fatal to them. **Miltiades** seized their persons, and made himself absolute in Chersonesus. To strengthen himself, he married Hegesipyla, the daughter of Olorus, the king of the Thracians. But his triumph was short-lived. In the third year of his government, his dominions were threatened by an invasion of the Scythian Nomades, whom Darius had some time before irritated by entering their country. **Miltiades** fled before them; but as their

hostilities were of short duration, he was soon restored to his kingdom. Three years afterwards he left Chersonesus, and set sail for Athens, where he was received with great applause. He was present at the celebrated battle of Marathon, in which all the chief officers ceded the power to him, and left the event of the battle to depend upon his superior abilities. He obtained an important victory over the numberless forces of his adversaries. Some time afterwards **Miltiades** was intrusted with a fleet of seventy ships, and ordered to punish those islands which had revolted to the Persians. He was successful at first, but a sudden report that the Persian fleet was coming to attack him, changed his operations as he was besieging Paros. He raised the siege, and returned to Athens. He was accused of treason, and particularly of holding correspondence with the enemy. The falsehood of these accusations might have appeared, if **Miltiades** had been able to come into the assembly. But a wound which he had received before Paros detained him at home; and his enemies, taking advantage of his absence, became more eager in their accusations, and louder in their clamours. He was condemned to death; but the rigour of his sentence was mitigated on the recollection of his great services to the Athenians, and he was imprisoned till he should pay a fine of fifty talents to the state. His inability to discharge so great a sum detained him in confinement; and his wounds having become incurable, he died a prisoner about 489 years before the Christian era. His body was ransomed by his son Cimon, who was obliged to borrow and pay the fifty talents, in order to give his father a decent burial. The accusations against **Miltiades** were probably the more readily believed by his countrymen, when they remembered how he had made himself absolute in Chersonesus. In condemning the barbarity of the Athenians towards a general who was the source of their military prosperity, we must also remember the jealousy which ever reigns amongst a free and independent people, and how watchful they are in defence of the natural rights which they see wrested from others by violence. Cornelius Nepos has written the life of **Miltiades** the son of Cimon; but his history is incongruous and unintelligible, from his confounding the actions of the son of Cimon with those of the son of Cypselus. Greater reliance is to be placed on the narrative of Herodotus, who was indisputably better informed and more capable of giving an account of the life and exploits of men who flourished in his age, and of which he could see the living monuments. Herodotus was born about six years after the battle of Marathon; and Cornelius Nepos, as a writer of the Augustan age, flourished about 450 years after the age of the father of history.

MILTON, a town of the county of Kent, in the hundred of Toltrintrough and lathe of Aylesford, twenty-three miles from London. It stands on the bank of the Thames, and forms the eastern part of the town of Gravesend. It is a thriving place, partly owing to being visited for bathing, as the river salts with the flood tide. It has some fortifications constructed to defend the passage of the river. The population amounted in 1801 to 2056, in 1811 to 2470, in 1821 to 2769, and in 1831 to 4348.

MILTON, or *Milton-Royal*, a town of the county of Kent, in the hundred of Milton and lathe of Scray, forty miles from London. It stands at the head of a navigable creek, in a swampy situation between Seltingbourne and the river Thames. It has a corporation governed by a portreeve; has a market on Saturday, and is principally known for the excellence of the oysters bred there. The population amounted in 1801 to 1622, in 1811 to 1746, in 1821 to 2012, and in 1831 to 2223.

Milton.

MILTON.

Milton.

JOHN MILTON, the immortal author of *Paradise Lost*, and, excepting Shakspeare, the greatest of the English poets, was born at his father's house in Bread Street, London, on the 9th, and baptized on the 20th of December 1608. Milton was by birth a gentleman, being descended from the proprietors of Milton, near Thame, in Oxfordshire, one of whom forfeited his estate in the times of York and Lancaster. The grandfather of the poet was under-ranger of the forest of Shotover, near Halton, and, being a zealous Catholic, disinherited his son because he had forsaken the faith of his ancestors. The father was educated as a gentleman, and became a member of Christ Church College, Oxford, where he probably imbibed those opinions which led him to change his religion, and thereby to incur disinherison. Being thus deprived of his patrimony, the father of the poet had recourse for his support to the profession of scrivener, in the practice of which he proved so successful, that he was enabled to give his children the advantages of a liberal education, and at length to retire with comfort into the country. He appears to have been an accomplished scholar, a man of refined taste, and a great proficient in music, a circumstance to which allusion is made by his son in his beautiful poem *Ad Patrem*.¹ He married a gentlewoman of the name of Caston, of a Welsh family, by whom he had two sons and a daughter. Christopher, the second son, was educated for the bar, and adhered to the royal cause, which at one time brought him into trouble; but soon after the accession of James II. he was rewarded with a knighthood, and appointed one of the barons of Exchequer. Anne, the only daughter, married a gentleman of the name of Philips, who rose to be secondary in the crown-office, and had by him two sons, John and Edward, who were educated by the poet.

It is to be lamented that so little information has reached us respecting the early life of our immortal poet. We know not for what profession his father had destined him, though it is certain that it was not the law; and we are equally in the dark regarding other matters connected with his early years. His education, however, was liberal, and the care with which it was conducted evinces the discernment and solicitude of his father. He had the benefit both of private and public tuition. His first instructor was Thomas Young, a puritan minister of Essex, who appears to have gained the affections of his pupil, and to have deserved the testimony which the latter has borne to his merits in an elegy and two Latin epistles. At what period this connection began or ended has not been ascertained. It seems probable that Young continued in his office until the time when, on account of his religious opinions, he withdrew to the continent, and became chaplain to the British merchants resident at Hamburg. Milton was then sent to St Paul's school, at that time under the direction of Dr

Gill, and remained some time at that seminary, distinguishing himself by almost incredible progress, and giving numerous indications of that gigantic intellect, the energies of which afterwards more fully developed themselves. Being thus initiated in several languages, and having already tasted the sweets of philosophy, he was, in the beginning of his sixteenth year, removed to Christ's College, Cambridge, where he entered as a pensioner, on the 12th of February 1624. He was committed to the tuition of Mr Chappell, the reputed author of *The Whole Duty of Man*, and afterwards successively provost of Trinity College, Dublin, dean of Cashel, and bishop of Cork and Ross.

At the time when he entered the university he was eminently skilled in the Latin language, and, by annexing dates to his first compositions, he has afforded us the means of estimating his early proficiency. At fifteen he translated or versified two Psalms (the 114th and 136th), which he thought worthy of publication, and in which may be discerned the dawning of real genius. This is still more apparent in his poem *On the Death of a Fair Infant*, which displays equal vigour and sensibility. Many of his elegies appear to have been written in his eighteenth year; and from them it is evident that he had then read the Roman authors with critical discernment. Indeed, Milton was the first Englishman who, after the revival of letters, wrote Latin verses with classical elegance. If any exceptions can be made, they are few in number. Haddon and Ascham, the pride of Elizabeth's reign, however they succeeded in prose, no sooner attempt verses than they provoke derision. Not many persons will, therefore, be inclined to agree with Johnson, that "the products of his vernal fertility have been surpassed by many, and particularly by his contemporary Cowley." Milton is not only the most learned of modern poets, but his writings show him to have been a man even from his very childhood; and hence Politian, Tasso, Cowley, Voltaire, Pope, and others, who have written poetical pieces of merit at an early age, must all bow to him as to a superior spirit. He also attracted particular notice by his academical exercises, some of which were published by him in his more mature years, as well as by several poems, both Latin and English, upon occasional subjects. Although his chief object seems to have been the cultivation of his poetical talents, he neglected no department of literature, and, by his persevering application, became "inured and seasoned betimes with the best and elegantest authors of the learned tongues."

He continued seven years at Cambridge, where he took both the usual degrees; that of bachelor in 1628, and that of master of arts in 1632. Of his conduct, and the treatment which he experienced in his college, much has been asserted, and but little proved. That "he left the university with no kindness for its institution," may be admitted even

Milton.

¹ The lines above referred to are the following, which strike us as being exceedingly beautiful:

Nec tu perge, precor, sacras contemnere Musas;
Nec vanas inopesque puta, quarum ipse peritus
Munere, mille sonos numeros componis ad aptos;
Millibus et vocem modulis variare canoram
Doctus Arionii merito sis nominis hæres.

Nor you affect to scorn the Aonian choir,
Blessed by their smiles, and glowing with their fire.
You! who by them inspired, with art profound,
Can wield the magic of proportioned sound:
Through thousand tones can teach the voice to stray,
And wind to harmony its mazy way,—
Arion's tuneful heir.

Milton. on the suspicious authority of Johnson. But if such a feeling existed in his mind, it must, from Johnson's own statement, have been produced "by the injudicious severity of his governors," and not the result of his "own captious perverseness," as the surly biographer has uncharitably insinuated. That Milton "obtained no fellowship, is," he tells us, "certain; but the unkindness with which he was treated was not merely negative. I am ashamed to relate," he adds, "what I fear is true, that Milton was one of the last students in either university that suffered the public indignity of corporal correction." Surely, injustice on the one hand, and personal outrage on the other, were not the most likely or natural means to beget "kindness" for the institution where such wrongs had been suffered. In the violence of controversial hostility, it was also objected to Milton that he had been expelled, or, to use the words of his original accuser, "vomited, after an inordinate and riotous youth, out of the university." But even Johnson admits that the charge "was apparently not true," and it is now quite certain that it was altogether false. Some time after taking his degree in arts, he left the university, and returned to his father's house at Horton, near Colebrook, in Berkshire. During his residence at Horton, he frequently visited London; and this circumstance, added to a reflection on the university, contained in the first of his elegies to Charles Diodati, written about the same time, was afterwards made the occasion of charging him with having been expelled from Cambridge for some misdemeanour, or with having left it in discontent because he could not obtain preferment; relinquishing his academical studies that he might spend his time in London, frequenting the playhouses, or keeping company with lewd women. Some lines in the same composition have often been cited or referred to as giving countenance to, if not altogether proving, this imputation.¹

Milton answered this calumny in his *Second Defence*, and his enemies had not the hardihood to repeat it. "Here,"

Milton. says he, speaking of the university, "I passed seven years in the usual course of instruction and study, with the approbation of the good, and without any stain upon my character, till I took the degree of master of arts. After this, I did not, as this miscreant feigns, run away into Italy, but of my own accord returned to my father's house, whether I was accompanied by the regrets of most of the fellows of the college, who showed me no common marks of friendship and esteem. On my father's estate, where he had determined to pass the remainder of his days, I enjoyed an interval of uninterrupted leisure, which I devoted entirely to the perusal of the Greek and Roman classics; though I occasionally visited the metropolis, either for the sake of purchasing books, or of learning something new in mathematics, or in music, in which I, at that time, found a source of pleasure and amusement. In this manner I spent five years, till my mother's death. I then became anxious to visit foreign parts, particularly Italy." Such is his own clear and distinct statement, which has never been contradicted, or at least refuted. In regard to the lines in the epistle addressed to Diodati, it must be obvious that they would never have been published if they had been conceived to contain any allusion to transactions dishonourable to the writer; and Milton himself, speaking of his calumniator, says, "He flings out stray crimes at a venture, which he could never, though he be a serpent, *suck from any thing that I have written*." The fact seems to be, that he had too strong and settled a distaste for episcopacy to think of entering the church as a profession; and that his lofty intellect and haughty spirit disdained to submit to the petty formalities and the pedantic discipline of the college, after he had made sufficient advances in learning to be able to pursue it himself, agreeably to the dictates of his own taste and genius.² He conceived, indeed, "that he who would take orders, must subscribe himself slave, and take an oath withal, which, unless he took with a conscience that could not retch, he must either strain, per-

¹ The whole support of the accusation preferred against Milton's college life is rested upon the following passage of the elegy addressed to Diodati:

Jam nec arundiferum mihi cura revisere Camum;
Nec dudum vetiti me laris angit amor:
Nuda nec arva placent, umbrasque negantia molles;
Quam male Phœbicolis convenit ille locus!
Nec duri libet usque minas perferre magistri
Cæteraque ingenio non subeunda meo.
Si sit hoc exilium patrios adisse penates,
Et vacuum curis otia grata sequi;
Non ego vel profugi nomen sortemve recuso,
Lætus et exilii conditione fruor.

From these lines both Johnson and Warton infer that he had incurred *rustication*, or a temporary removal from Cambridge, with perhaps the loss of a term. The words *vetiti laris*, and afterwards *exilium*, which is twice used in reference to himself, scarcely admit of any other interpretation. But the supposition of any immoral irregularity is excluded by many considerations. Had he been conscious of having justly incurred censure and punishment, he would never have said "*Lætus et exilii conditione fruor*." Besides, the same poem which mentions his *exile*, proves that it was not perpetual; for it concludes with a resolution of returning to Cambridge. His declaration that he is weary of enduring "the threats of a rigorous master, and something else which a temper like his can ill brook," seems to suggest the true explanation of the difficulty. Though not chargeable with immoral irregularities, he might, upon other accounts, have become obnoxious to the governors of his college. He might have offended their prejudices by the bold avowal of his puritan opinions; or he might have wounded their pride by exposing their negligent or injudicious discharge of duty; or he might have excited their displeasure by a haughty inattention to their rules, by refusing to exchange the pleasure of banqueting on the works of Plato or of Homer, for the barren fatigue of translating a sermon, or loading his memory with cumbersome pages of scholastic theology. A mere technical breach of discipline is all that can be legitimately inferred or supposed; and, from the frankness with which he has perpetuated the fact of his *exile*, we may be well assured that its cause was such as gave him no shame.

² In the *Apology for Smectymnus*, Milton, speaking of the universities, has afforded us the means of ascertaining his thoughts and feelings respecting these institutions. Having described many individuals of the parliament as descended from the ancient and high nobility, he adds: "Yet had they a greater danger to cope with; for being trained up in the knowledge of learning, and sent to those places which were intended to be the seed-plots of piety and the liberal arts, but were become the nurseries of superstition and empty speculation, as they were prosperous against those vices which grow upon youth out of idleness and superfluity, so were they happy in working off the harms of their absurd studies and labours; correcting by the clearness of their own judgment the errors of their *misinstruction*, and were, as David was, wiser than their teachers. And, although their lot fell into such times, and to be bred in such places, where if they chanced to be taught any thing good, or of their own accord had learnt it, they might see that presently untaught them by the ill example of their elders." If Milton, when at Cambridge, was in the habit of speaking such plain truths as are contained in this passage, that "nursery of superstition and empty speculation" must have withal dealt gently by the young heretic, in inflicting on him no higher punishment than that of "rustication."

Milton. force, or split his faith;" wherefore he "thought it better to prefer a blameless silence before the office of speaking, bought and begun with servitude and forswearing."

During the five years which Milton spent under his father's roof at Horton, and which may justly be regarded as the happiest of his life, he produced some of the finest specimens of his genius; as extraordinary for their copiousness and command of early fable and history, as for the harmony of their numbers, and the sublimity and purity of their conceptions. The *Comus* in 1634, and the *Lycidas* in 1637, were unquestionably written at Horton; and there is strong internal evidence to prove that the *Arcades*, *L'Allegro*, and *Il Penseroso*, were also composed in the same rural retreat, during this season of propitious leisure. The *Mask of Comus* was acted before the Earl of Bridgewater, president of Wales, at Ludlow Castle, in 1634; upon which occasion the character of the lady and her two brothers were represented by Lady Alice Egerton, then about thirteen years of age, and her two brothers, Lord Brackley and the honourable Thomas Egerton, who were still younger. The story of the piece is said to have been suggested by the circumstance of Lady Alice having been separated from her company in the night, and having wandered for some time by herself in the forest of Haywood, as she was returning from a distant visit to meet her father, upon his taking possession of his presidency.

Comus,¹ or revelry, had already been personified in a sublime passage of the *Agamemnon* of Æschylus; and the jolly god had been introduced upon the English stage in a written *Mask* by Ben Jonson. But it was reserved for Milton to develop his form and character, to give him a lineage and an empire, and to make him the hero of one of the most exquisite dramatic poems which the genius of man has ever produced. The *Comus* is framed upon the model of the Italian *Masque*, and is certainly the noblest production of the kind which exists in any language. It is dramatic only in semblance. The finest passages are those which are lyrical in form as well as in spirit. "I should much commend the tragical part," says Sir Henry Wotton, "if the lyrical did not ravish me with a certain dorique delicacy in the songs and odes, whereunto I must plainly confess, that I have seen yet nothing parallel in our language." It is when Milton escapes from the shackles of dialogue, and feels himself at liberty to indulge his choral raptures without reserve, that he rises above himself, and expatiates in celestial freedom and beauty. Then, to use the impassioned expressions of an eloquent writer, "he seems to skim the earth, to soar above the clouds, to bathe in the Elysian dew of the rainbow, and to inhale the balmy odours of nard and cassia, which the musky wings of the zephyr scatter through the cedared valleys of the Hesperides."²

The *Lycidas* was written to commemorate the death of Mr Edward King, the son of Sir John King, secretary for Ireland in the reigns of Elizabeth, James, and Charles. Young King was a great favourite at Cambridge, where his learning, piety, and talents had secured universal respect, and his untimely fate was deplored as a public loss. He perished by shipwreck in his passage from Chester to Ireland, the vessel on board of which he was having foundered in a calm sea at no great distance from land. In a collection of poems, published in 1638, *Lycidas* occupies the last, and (as it was no doubt intended to be) the most honourable place; but we may reasonably wonder how a production, breathing such hostility to the clergy of the Church of England, and even menacing their leader with

the axe, should have been permitted to issue from the university press. The guardians of the church must surely have been slumbering at their posts; or, perhaps, this poem being only part of a collection, it was not scrutinized before it went to press. The most objectionable part of the composition is the speech assigned to St Peter, "the pilot of the Galilean lake," and it is also inferior in poetical merit to what precedes and follows it. But, taking the monody as a whole, it is indubitably instinct with high genius, and an effusion of the purest and most exalted poetry. The *Arcades* is evidently nothing more than the poetical part of an entertainment, the bulk of which consisted of prose dialogue and machinery; yet, whatever proportion it constituted of the piece, it must have imparted a value to the whole, displaying, as it does, a kindred though inferior lustre to that which irradiates the dramatic poem of *Comus*. *L'Allegro* and *Il Penseroso* first appeared in a collection of Milton's poems published in 1645; but the precise time of their production has not been ascertained. There is reason to believe, however, that they were written at Horton, in the interval between the composition of *Comus* and that of *Lycidas*; though it is not easy to adjust the precedence between these victorious efforts of the descriptive muse. They were certainly composed in the happiest mood of the poet's mind, when his fancy disported in glorious sunshine, and no cloud or star interposed to obstruct or darken her perceptions.

Milton, having lost his mother in 1627, when he was about twenty-nine years of age, now felt himself at liberty to carry into effect a project which he had long meditated; and having obtained his father's concurrence, he resolved to visit foreign parts, and particularly Italy. His reason for wishing to travel in foreign countries was, as Toland quaintly expresses it, a persuasion "that he could not better discern the pre-eminence and defects of his own country than by observing the customs and institutions of others; and that the study of never so many books, without the advantages of conversation, serves either to render a man a stupid fool or a pedant."³ He left England in 1638, and proceeded to Paris, whence, after a short stay, he hastened to Italy, the grand object of his curiosity; and, after an absence of a year and three months, the greater part of which was spent in that classic region, he returned home through France. The only account of his travels is that furnished by himself, in his brief autobiography; and, as no one can describe Milton so well as himself, we shall give it in his own words, rather than attempt to paraphrase it, after the absurd fashion of his biographers.

"I became anxious to visit foreign parts, and particularly Italy. My father gave me his permission, and I left home with one servant. On my departure, the celebrated Henry Wotton, who had long been King James's ambassador at Venice, gave me a signal proof of his regard, in an elegant letter which he wrote, breathing not only the warmest friendship, but containing some maxims of conduct which I found very useful in my travels."⁴ The noble Thomas Scudamore, King Charles's ambassador, to whom I carried letters of recommendation, received me most courteously at Paris. His lordship gave me a card of introduction to the learned Hugo Grotius, at that time ambassador from the Queen of Sweden to the French court; whose acquaintance I anxiously desired, and to whose house I was accompanied by some of his lordship's friends. A few days after, when I set out for Italy, he gave me letters to the English merchants on my route, that they might show me any civilities in their power.

¹ *Kompos*.

² Edinburgh Review, vol. xlii. p. 315.

Life of Milton, p. 9.

Amongst these maxims is that "Delphian oracle" of prudence which Wotton himself had been taught by his friend Alberto Scipioni. "Signor amico mio," said the old Roman courtier, "i pensieri stretti, ed il viso sciolto," will go safely over the world, without offence of others, or of your own conscience.

Milton. "Taking ship at Nice, I arrived at Genoa; and afterwards visited Leghorn, Pisa, and Florence. In the latter city, which I have always particularly esteemed for the elegance of its dialect, its genius, and its taste, I stopped about two months; when I contracted an intimacy with many persons of rank and learning, and was a constant attendant at their literary parties; a practice which prevails there, and tends so much to the diffusion of knowledge and the preservation of friendship. No time will ever abolish the agreeable recollections which I cherish of Jacob Gaddi,¹ Carolo Dati,² Frescobaldo, Cultellero, Bonomathai, Clementillo, Francisco, and many others. From Florence I went to Sienna, thence to Rome; where, after I had spent about two months in viewing the antiquities of that renowned city, where I experienced the most friendly attentions from Lucas Holstein,³ and other learned and ingenious men, I continued my route to Naples. There I was introduced, by a certain recluse with whom I had travelled from Rome, to John Baptista Manso, marquis of Villa, a nobleman of distinguished rank and authority, to whom Torquato Tasso, the illustrious poet, inscribed his book on Friendship.⁴ During my stay, he gave me singular proofs of his regard; he himself conducted me round the city, and to the palace of the viceroy; and more than once paid me a visit at my lodgings. On my departure, he gravely apologised for not having shown me more civility, which he said he had been restrained from doing, because I had spoken with so little reserve on matters of religion.

"When I was preparing to pass over into Sicily and Greece, the melancholy intelligence which I received of the civil commotions in England, made me alter my purpose; for I thought it base to be travelling for amusement abroad, while my fellow-citizens were fighting for liberty at home. While I was on my way back to Rome, some merchants informed me that the English Jesuits had formed a plot against me, if I returned to Rome, because I had spoken too freely of religion; for it was a rule which I laid down to myself in those places, never to be the first to begin any conversation on religion; but if any questions were put to me concerning my faith, to declare it without any reserve or fear. I nevertheless returned to Rome. I took no steps to conceal either my person or my character; and for about the space of two months I again openly defended, as I had done before, the reformed religion, in the very metropolis of Popery.

"By the favour of God I got back to Florence, where I was received with as much affection as if I had returned to my native country; there I stopped as many months as I had done before, except that I made an excursion of a few days to Lucca, and crossing the Apennines, passed through Bologna and Ferrara to Venice. After I had spent a month in surveying the curiosities of this city, and had put on board a ship the books which I had collected

in Italy, I proceeded through Verona and Milan, and along the Leman Lake to Geneva. Milton.

"The mention of this city brings to my recollection the slandering More,⁵ and makes me again call the Deity to witness, that in all those places where vice meets with so little discouragement, and is practised with so little shame, I never once deviated from the paths of integrity and virtue; and perpetually reflected, that, although my conduct might escape the notice of men, it would not elude the inspection of God. At Geneva I held daily conferences with John Diodati, the learned professor of theology.

"Then, pursuing my former route through France, I returned to my native country, after an absence of about one year and three months, at the time when Charles, having broken the peace, was renewing what is called the Episcopal war with the Scots; in which the royalists being routed in the first encounter, and the English being universally and justly disaffected, the necessity of his affairs at last obliged him to convene a parliament."⁶

Upon his return to England, Milton, it seems, could discover no way in which he might directly serve the cause of the people. He was not formed for participating in the rough and fierce encounters of the field; he wanted both the means and the connections necessary to enable him to take any share in the management of public affairs; and the time had not yet arrived, in the development of the drama, when the part which alone he was eminently qualified to sustain could be brought upon the stage. He therefore hired a house in St Bride's Church-yard, and renewed his literary pursuits, calmly awaiting the issue of the contest, which he trusted "to the wise conduct of Providence, and to the courage of the people." Here he consented to receive as pupils his two nephews, John and Edward Philips; and subsequently, yielding to the importunities of some intimate friends, he added to their number. Finding his apartments too small, he now took a house in Aldersgate Street, where he received more boys, and instructed them in Latin, Greek, and Hebrew, with its dialects, as well as in mathematics, cosmography, history, and some modern languages, particularly French and Italian. "This," says Dr Johnson, "is the period of his life from which all his biographers seem to shrink. They are unwilling that Milton should be degraded to a schoolmaster; but since it cannot be denied that he taught boys, one finds out that he taught for nothing, and another that his motive was only zeal for the propagation of learning and virtue; and all tell what they do not know to be true, only to excuse an act which no wise man will consider as in itself disgraceful. His father was alive; his allowance was not ample; and he supplied its deficiencies by an honest and useful employment."⁷ Milton, in his little circle of scholars, was usefully if not splendidly employed; and no man of sense can suppose that, whilst he was occupied in pro-

¹ The historical painter.

² A Florentine nobleman, author of an Essay on the Discoveries of Galileo, and of Lives of the Ancient Fathers.

³ The librarian of the Vatican.

⁴ This nobleman composed a Latin distich, which he addressed to Milton:

Ut mens forma, decor, facies mos; si pietas sic,
Non Anglus, verum, hercle, Angelus ipse fores.

⁵ The *Clamor Regii Sanguinis ad Cælum* to which the *Defensio Secunda pro Populo Anglicano* (whence the above passage is extracted) was the answer, is now known to have been written by Peter du Moulin; but having been published by Alexander Morus or More, it was at first supposed to have been the production of that individual.

⁶ Prose Works, edited by Fletcher, pp 993, 996.

⁷ The strong good sense of these observations contrasts forcibly with the unwieldy "merriment" of Johnson "on great promises and small performance; on the man who hastens home, because his countrymen are contending for their liberty, and, when he reaches the scene of action, vapours away his patriotism in a private boarding-school." The sneer contained in these words is characteristic only of the writer by whom they are employed, and whose bad feeling towards the author of *Paradise Lost* shows itself on so many occasions. Milton's "patriotism," as we shall soon find, was not so volatile as to evaporate even under the hardest trials of adversity; and he will be honoured and revered for his steady and consistent attachment to liberty, long after the rhetorical exaggerations of his enemies have sunk into merited oblivion.

Milton. moting the highest interests of some of his species, he was degrading himself in the estimation of the rest.

Toland has described the nature of the education which he aimed at bestowing upon his pupils, and which involved a great innovation upon the established practice. In this, as in many other respects, Milton appears to have been greatly in advance of his age. His purpose was to teach something more solid than the common literature of the schools; to expand the faculties and to inform the judgments of his pupils, by combining the knowledge of things with that of words, instead of subjecting them to the irksome and comparatively useless task of acquiring the mere knowledge of words, without any adequate conception of those ideas or objects of which they are the representatives. Not content with those books which are commonly used in the schools, he placed in the hands of his disciples such ancient works as were capable of affording information in various departments of science; and "a formidable list" is given of the authors, Greek and Latin, which were read in Aldersgate Street, by youth between fifteen and sixteen years of age. That he perhaps attempted to do more than any degree of diligence or industry could accomplish, may be admitted without impeaching the soundness of the principle upon which he proceeded; and although "nobody can be taught faster than he can learn," yet it is at least equally certain, that some teachers can make young men learn much faster than others, and that, in general, the comparative progress of the pupil is a pretty fair measure of the diligence and skill of the master. He set his pupils an example of close application and spare diet; indeed abstinence was one of his favourite virtues, which he practised invariably through life; and the only indulgence which he allowed himself was passing a day of temperate festivity once in three weeks or a month.¹ "One part of his system," says Johnson, "deserves general imitation. He was careful to instruct his scholars in religion. Every Sunday was spent upon theology, of which he dictated a short system, gathered from the writers that were then fashionable in the Dutch universities."

But whilst Milton's occupation as a teacher preserved his familiarity with the Greek and Roman authors, it precluded him from discharging what he conceived to be his duties as a citizen, and defeated the patriotic object which had recalled him from the shores of Sicily and Greece. From his first acquaintance with the struggles of his country, he had determined to devote himself to her service; and the time seemed now to have arrived for carrying his pur-

pose into effect. Conscious of his own strength, and sensible that genius, armed with knowledge, would prove a more powerful auxiliary to the popular cause than if he had carried ten battalions into the field, he decided in favour of the pen against the sword, and took his position on ground whence no adversary was able to dislodge him.

The long parliament, representing a nation alarmed and irritated by many flagrant abuses of power, had now assembled, and evidently possessed a strong sympathy with the public feeling. The king's violent conduct to former parliaments, in imprisoning refractory members, one of whom had died under the length and rigour of his confinement; his unconstitutional attempts to govern by prerogative alone; his arbitrary exactions in violation of all law; and the severe sentences with which his council and his courts abetted and enforced his reckless despotism; these and many other causes had concurred in alienating the affections of all orders of the community, and preparing their minds for resistance and innovations. The leaders of the church party imitated the despotic policy of the court; and their rigorous persecution of the puritans, offensive alike to the feelings of the humane and the common sense of the enlightened, excited against them the fears of the good and the jealousies of the wise. The power of the episcopal courts had been everywhere urged into unusual activity by the superintendence and incitement of the high commission; and almost every diocese had witnessed scenes of rigour similar to those which had at once disgraced and exasperated the capital.² There were not wanting in the church some men of learning and piety; at this unfortunate crisis she could boast, amongst her prelates, of a Williams, a Davenant, a Hall, and an Usher; but at their head was placed the domineering and intolerant Laud, a man of narrow views, unrelenting zeal, and abject superstition, who, unrestrained by any considerations of prudence, took care on every occasion to magnify the regal authority, and sought by all possible means to extend that tyranny which supported his own.³

Milton, a diligent and attentive observer of all that was passing around him, having discerned in the church the source of much of the political and social evil which had assumed so frightful an aspect, as well as the grand engine of oppression in the hands of the king, now came to the resolution of taking an active part in the rude conflict of affairs. The moment was propitious for an assault upon the prelacy. The parliament had impeached the bigoted and persecuting primate; they had rescued his victims from their dun-

¹ This day was allotted to the society of some young and gay friends; according to Johnson, it was usually spent "with some gay gentlemen of Gray's Inn." But, as Dr Symmons observes, the gay men of the puritan age were mere babies in excess, compared with the revellers of that which succeeded it, when the profligacy of a shameless court spread like a contagion throughout the land, tainting life and manners as well as literature with a debasing immorality; and when modesty and temperance were hooted out of countenance by wild riot and obstreperous vice.

² Symmons's *Life of Milton*, p. 215.

³ Hume, in his character of Archbishop Laud, has thrown in some softening shades of colour, by representing him as "virtuous" and "disinterested," a man of violent prejudices and imperious temper, yet of upright intentions and honest purposes. The historian admits, however, that he led the king "into a conduct which proved fatal to himself and to his kingdom;" and that "all his measures tended to a most popish state of ceremonies in worship, and tyranny and intolerance in behaviour." But Mrs Hutchison has been more particular in her description of Laud's arbitrary and tyrannical policy. "The payment of civil obedience to the king and the laws of the land satisfied not," says that incomparable woman; "if any durst dispute his impositions in the worship of God, he was presently reckoned among the seditious and disturbers of the public peace, and accordingly persecuted; if any were grieved at the dishonesty of the kingdom, or the griping of the poor, or the unjust oppressions of the subject by a thousand ways, invented to maintain the riots of the courtiers, and the swarms of needy Scots the king had brought in to devour like locusts the plenty of this land, he was a puritan; if any, out of mere morality or civil honesty, discountenanced the abominations of those days, he was a puritan, however he conformed to their superstitious worship; if any showed favour to any godly, honest persons, kept them company, relieved them in want, or protected them in violent or unjust oppression, he was a puritan; if any gentleman in his country maintained the good laws of the land, or stood up for any public interest, for good order or government, he was a puritan; in short, all that crossed the views of the needy courtiers, the proud encroaching priests, the thievish projectors, the lewd nobility and gentry, whoever was zealous for God's glory or worship, &c. were puritans; and if puritans, then enemies to the king and his government, seditious, factious, hypocrites, ambitious disturbers of the public peace, and, finally, the pest of the kingdom." "As such," she adds, "they not only made them the sport of the pulpit, which was become but a more solemn sort of stage; but every stage, and every table, and every puppet-play, belched forth profane scoffs upon them; the drunkards made them their songs; all fiddlers and mimics learned to abuse them, as finding it a most gameful way of fooling." (*Memoirs of Colonel Hutchinson*, vol. i. pp. 122, 123, 124.)

Milton. geons, recalled his exiles to behold his fall, released the press from its "horrid silence," and permitted it to pour out its long-imprisoned vengeance on the heads of the oppressor and his followers. "The rigour of the parliament," says Milton, "had begun to humble the pride of the bishops. As long as the liberty of speech was no longer subject to control, all mouths began to be opened against the bishops; some complained of the vices of the individuals, others of those of the order. They said it was unjust that they alone should differ from all other reformed churches, and particularly the word of God. This awakened all my attention and my zeal: I saw that a way was opening for the establishment of real liberty; that the foundation was laying for the deliverance of man from the yoke of slavery and superstition; that the principles of religion, which were the first objects of my care, would exert a salutary influence on the manners and constitution of the republic; and as I had from my youth studied the distinctions between religious and civil rights, I perceived that, if I ever wished to be of use, I ought at least not to be wanting to my country, to the church, and to so many of my fellow Christians, in a crisis of so much danger. I therefore determined to relinquish the other pursuits in which I was engaged, and to transfer the whole force of my talents and my industry to this one important object." Influenced by these views, Milton emerged from his solitude, and took up his weapon for his country.¹

In 1641 appeared the first of his works, which was entitled, *Of Reformation touching Church Government in England, and the Causes that have hitherto hindered it*. This treatise consists of two books, the object of which is to demonstrate the proposition that prelacy is essentially inimical to civil liberty. In the opinion of the author, the reformation in the church had not proceeded to the proper extent; and the suspension of its progress he attributes principally to its prelates, "who, though they had renounced the pope, yet hugged the popedom, and shared the authority among themselves." He declares, with impressive solemnity, that wherever, in this book, he has laid open the faults and blemishes of fathers, martyrs, or Christian emperors, he has done so "neither out of malice, nor list to speak evil, nor any vain glory, but of mere necessity to vindicate the spotless truth from an ignominious bondage." In prosecution of this grand object he displays a profundity of learning, a vigour of reasoning, an earnestness of purpose, an impassioned eloquence of style, and a comprehensive grasp of his subject, which must ever excite admiration; indeed, the work is throughout one continued strain of wisdom and eloquence. The bishops, of

Milton. course, receive no quarter at his hands. He tears the veil of hypocrisy from their hearts; exposes their worldly-mindedness and love of pelf and power; and having animadverted on the conduct of the prelacy in former times, he portrays, with unsparing severity, its character in his own,² reproving the unconcern with which the bishops extorted large incomes from the nation, as well as the profligacy with which they expended their revenues, and contending that prelacy is one of those forms of evil which are "the same yesterday, and to-day, and for ever." To this and other attacks from the pens of puritan writers, Hall, bishop of Norwich, replied in *An Humble Remonstrance to the High Court of Parliament*; and about the same time Usher, archbishop of Armagh, published *The Apostolical Institution of Episcopacy*. In answer to these able and learned works, Milton wrote two pieces, one of them entitled *Of Prelatical Episcopacy*, and the other, *The Reason of Church Government urged against Prelacy*.³ He had now entered fairly into this great controversy, and he was not disposed to shrink from the labour or the responsibility of carrying it on. "When two bishops of superior distinction," he observes, "vindicated their privileges against some principal ministers, I thought that, on those topics, to the consideration of which I was led solely by my love of truth, and my reverence for Christianity, I should probably not write worse than those who were contending only for their own emoluments and usurpations." Nor did he form an erroneous or exaggerated estimate of his own powers. These productions of Milton, distinguished by vigour, acuteness, and erudition, were unquestionably the most able, eloquent, and learned on the puritan side of the controversy. But the publication which appears to have attracted most attention at the time was a pamphlet, the joint production of five presbyterian divines, under the appellation of Smectymnuus, a word formed from the initial letters of the name of the authors.⁴ To this production Bishop Hall replied in a *Defence of the Remonstrance*; and Milton's formidable pen, again employed in opposition to the prelates, produced *Animadversions on the Remonstrant's Defence*, a work which is thrown into the form of a dialogue between the remonstrant and his antagonist, who answers him. "Why this close and succinct manner was rather to be chosen," says the author, "this was the reason; chiefly that the ingenious reader, without further amusing himself in the labyrinth of controversial antiquity, may come to the speediest way to see the truth vindicated, and sophistry taken short at the first bound." In this production the replies are always severe, frequently jocose; and there prevails through-

¹ It was not from moral cowardice, as Johnston has insinuated, that Milton preferred the pen to the sword, the closet to the field. "I did not," says he in his *Defensio Secunda*, "for any other reason decline the dangers of war, than that I might in another way, with much more efficacy, and with not less danger to myself, render assistance to my countrymen, and discover a mind neither shrinking from adverse fortune, nor actuated by any improper fear of calumny or of death. Since, from my childhood, I had been devoted to the more liberal studies, and was always more powerful in my intellect than in my body, avoiding the labours of the camp, in which any robust common soldier would have surpassed me, I betook myself to those weapons which I could wield with the most effect; and I conceived that I was acting wisely when I thus brought my better and more valuable faculties, those which constituted my principal strength and consequence, to the assistance of my country and her honourable cause." Can any one read this without assenting to its justice, or admiring the motives which determined the choice of the immortal writer?

² Here is the process for transforming a modern into a primitive bishop. "He that will mould a modern bishop into a primitive, but yield him to be elected by the popular voice, undiocesed, unrevenued, unlorded, and leave him nothing but brotherly equality, matchless temperance, frequent fasting, incessant prayer and preaching, continual watchings and labours in his ministry; which, what a rich booty it would be, what a plump endowment to the many-benefice-gaping mouth of a prelate, what a relish it would give to his canary-sucking and swan-eating palate, let old Bishop Mountain judge for me." (*Prose Works*, p. 6.)

³ In this book, he discovers, not with ostentatious exultation, but with calm confidence, his high opinion of his own powers; and promises to undertake something, which may prove both useful and honourable to his country. "This," says he, "is not to be obtained but by devout prayer to the Eternal Spirit, that can enrich with all utterance and knowledge, and sends out his Seraphim with the hallowed fire of his altar, to touch and purify the lips of whom he pleases. To this must be added, industrious and select reading, steady observation, and insight into all seemly and generous arts and affairs; till which in some measure be compass'd, I refuse not to sustain this expectation." What can be more noble or more affecting than the aspiration here breathed out, in prophetic announcement of the imperishable monument which he was destined to raise, and upon which his name and fame were to be written in characters of unextinguishable glory! It seems to have moved even the obduracy of Johnson. "From a promise like this," says he, "at once fervid, pious, and rational, might be expected the *Paradise Lost*."

⁴ Stephen Marshal, Edward Calamy, Thomas Young, Matthew Newcommen, and William Spurstow.

Milton. out the piece a sort of grim smile of derision, which sharpens and aggravates the severity. These various publications were written in the course of one year, 1641, when their author was only thirty-three years of age, and occupied with the fatiguing duties of an instructor of youth; a circumstance which cannot fail to excite wonder at the unwearied industry, the ready application of various knowledge, and the exuberant fertility of mind, which are displayed in their composition.

In the beginning of 1642, the *Animadversions*, which are unquestionably personal and offensive, elicited a reply that was supposed to emanate from a son of the insulted bishop, and appeared under the title of a *Modest Confutation of a Slandrous and Scurrilous Libel*. If this reply had been published with its author's name, the motive would probably have atoned with Milton for its virulence. But the publication was anonymous; and in it Milton was not only treated with contumely and insult, but assailed with enormous falsehoods, random accusations, and the most rancorous personal vituperation. He was, however, "dauntless, defiant, and, when insulted, fierce." In his *Apology for Smectymnuus*, the result of this accumulated provocation, he proved himself a match for his adversaries even at their own weapons, and, what is of more importance, successfully vindicated his character from the foul imputations which had been cast upon it. On this occasion, there was every excuse for the warmth of Milton's reply, and the unscrupulous vigour with which he poured his overwhelming sarcasms on his assailants. He had been accused of lewdness and sensuality; other crimes had been darkly hinted at; and his fellow Christians had been called upon "to stone the miscreant to death." Besides, he knew that others were partakers of his adversary's sins; that the latter was but the organ or mouthpiece of the episcopal order; and that, in the most bitter and malignant aspersions of his character, his reviler had their approbation and concurrence. This naturally turned the edge of his weapon against the bishops, to whom he never misses an opportunity of expressing his hostility. In fact, it was as much out of his power to alter or soften the style in which he wrote, as to dissolve the groundwork of nature which God has created in him. It was the full reflection of his very soul, whatever might be the state of its emotions; a mirror which showed the various workings of that great and glorious spirit with which God had endowed him. In noticing the charge, that he had been "vomited out of the university," he keenly remarks, "Of small practice were the physician who could not judge, by what she and her sister have of long time vomited, that the worser stuff she strongly keeps in her stomach, but the better she is ever keeking at, and queasy; she vomits now out of sickness; but before it be well with her, she must vomit with strong physick." The picture he draws of the university-men is marked with equal severity. "What with truanting and debauchery," says he, "what with false grounds, and the weakness of natural faculties in many of them, perhaps there would be found among them as many unsolid and corrupted judgments, both in doctrine and life, as in any other two corporations of the like bigness. This is undoubted, that if any carpenter, smith, or weaver, were

such a bungler in his trade, as the greater number of them are in their profession, he would starve for any custom; and should he exercise his manufacture as little as they do their talents, he would forget his art; or, should he mistake his tools as they do theirs, he would mar all the work he took in hand."¹

Dr Symmons, with the natural bias of a churchman, thinks that "the learning of Usher, and the wit of Hall, preponderated in the contest;" and that this, he says, "seems to have been felt not only by the Smectymnuan divines, but by Milton himself." As to the former part of this judgment, it is matter of opinion and taste, in regard to which different men will come to different conclusions; though, if the balance of learning and wit was on the side of the prelates, the balance of genius and eloquence was decidedly on that of the puritans. Nor, on the other hand, have we been able to discover any indications which would lead us to infer that Milton was really sensible of the "preponderance" here somewhat gratuitously ascribed to his opponents. So far from this, there is evidence to show that his conviction was directly the contrary of that here imputed to him. From a just confidence in his own powers, he assumes and maintains throughout a tone of lofty superiority, and vindicates his title to pre-eminence, by the unrivalled ability and eloquence with which he repulses the assaults of his adversaries, and defends what he believes to be the cause of truth and of God. And the impression made by his writings was commensurate with their power. When he first directed his attention to the evils growing out of the church, there was a strong public feeling against it; but that feeling was vague, and, wanting direction, was expending itself in useless declamation. Milton, and those who laboured with him in the same cause, turned it into a definite channel, and rendered it productive of great and important results.² We may admire the abilities of Usher and of Hall, and even admit, with Dr Symmons, that if the church, at this crisis, could have been upheld, it would have been supported by these prelates; but the evils growing out of the system were too great, the abuses and corruptions were too gross, the tyranny exercised was too flagrant and exasperating, to be shielded or upheld by any talents, especially when laid bare, in all their hideous deformity, by the unsparing hand of so formidable an adversary as Milton.

We come now to an event in Milton's life which had a material influence on his domestic comfort, and gave a new direction to his literary labours. This was his marriage, in 1648, to Mary, eldest daughter of Mr Richard Powell, of Forest Hill, near Shotover, in Oxfordshire. His choice seems to have been the suggestion of fancy alone, and its consequences were such as might have been expected from so imprudent a connection. The lady was brought to London by her husband, who placed her at the head of his frugal establishment, and expected, no doubt, to enjoy all the delights of conjugal happiness. But in this he was destined to be cruelly disappointed. The lady, who was of a royalist family, and accustomed to the affluent hospitality of her father's house, appears to have had no relish for the pleasures of spare diet and hard study; for, as Philips relates, "having for a month led a philosophic life, after

¹ Prose Works, p. 92.

² In December 1640, a petition was presented to the House of Commons, signed by fifteen thousand citizens of London, praying the legislature to suppress the archbishops and bishops. Early in 1641, a bill was passed by the Commons, "to restrain bishops, and others in holy orders, from intermeddling in secular affairs;" it was sent up to the Lords on the 1st of May, and having met with great opposition, was finally rejected. A bill was now introduced, and by a large majority read a second time in the Commons, "for the utter abolishing and taking away of all archbishops, bishops, their chancellors and commissaries, deans, deans and chapters, chanters, canons, and other under officers, out of the church of England." On the 5th of February 1642, this bill passed the House of Lords, and on the 14th of the same month it received the royal assent. So rapid was the progression of that cause, to the advancement of which Milton had devoted his commanding talents and eloquence. By one fell blow the hierarchy was levelled with the dust.

Milton. having been used at home to a great house, and much company and joviality, her friends, possibly by her own desire, made earnest suit to have her company the remaining part of the summer; which was granted, upon a promise of her return at Michaelmas." The time fixed arrived, but the lady did not appear, and Milton wrote a letter urging her immediate return. The letter remained unanswered, and several others which followed were treated in the same manner. Incensed at such conduct, her husband at length despatched a messenger to her father's house, with instructions to bring her to London. But this also failed. The messenger was rudely dismissed, and the wife remained with her friends. The prosperous fortunes of the king, whose forces had defeated those of the parliament under Fairfax and Waller, probably emboldened the Powells, who were cavaliers, to take this mode of breaking off the alliance. Such, at least, is the conjecture of Dr Symmons.

Milton was not of a temper to submit patiently to injustice aggravated by insult. He resolved to repudiate his wife, upon the grounds of disobedience and desertion; and to justify this step to the world, he published, in 1644, *The Doctrine and Discipline of Divorce*, which he inscribed to the parliament. This treatise was soon followed by the *Judgment of Martin Bucer concerning Divorce*; and, next year, by *Tetrachordon* and *Colasterion*, the last being a reply to an anonymous antagonist. In these writings, he argued the question with very great ingenuity,¹ but made few converts, and even incurred the censure of a body whom he had sought to propitiate. No sooner had they appeared than the fury of the presbyterian clergy was kindled against the author. Unmindful of the recent and important services which he had rendered them, they now assailed him, from the pulpit and the press, with violent and acrimonious hostility. They even endeavoured to make the legislature the instrument of their vengeance, and actually caused him to be summoned before the House of Lords. But from that tribunal he was honourably dismissed; and all that the Presbyterians gained by their ill-timed zeal was the loss of an able friend, and the excitement of a dangerous enemy. Milton was now irrevocably alienated from their cause. He had discovered that these pretended zealots of liberty sought only their own aggrandisement, and the power of imposing upon others that very yoke which they had themselves been unable to bear.

Milton certainly entertained the opinions he professed; and, to evince his consciousness of freedom, he proceeded to pay his addresses to a beautiful and accomplished young woman, the daughter of a Dr Davis, who seems to have entertained his suit. This alarmed his wife and her relations, who, finding that Milton was not an unresisting sufferer of injuries, now became anxious for a reconciliation; and they were probably the more sincere in their desire, that, from the desperate situation of the royal cause, which had been ruined by the decisive battle of Naseby, they began to be sensible that they might need his protection. The plan for the accomplishment of their purposes was conceived and executed with successful ingenuity. Combining with Milton's friends, who concurred in the wish for a reconciliation, they watched his visits; and, when he was in the house of a relation, they stationed his wife in an inner apartment, with instructions to appear at the pro-

per time, and to implore his pardon on her knees. The lady enacted her part to admiration, throwing herself at his feet, confessing her fault, and with tears entreating his forgiveness. For a moment Milton appeared to be inexorable; but his firmness soon gave way, and yielding to the impulse of his own generous nature, he raised her from the ground, consented to forget the past, and took her home to his bosom and affections. Nor was this all. He extended his placability to those who had been the abettors, if not the instigators, of his wife's desertion; and receiving her father and her brothers under his roof, he supported them by the fruits of his labours in their day of danger and distress. In this asylum they remained until, by his influence and exertions, the question respecting their property was adjusted with the government in the year 1647.

The same year, 1644, which saw Milton immersed in the controversy about divorce, beheld him also imparting to the world his ideas on the subject of education, and defending, with matchless power, the freedom of the press. His *Tractate on Education* is addressed to Mr Samuel Hartlib, to whom Sir William Petty afterwards inscribed one of his early works, and who was equally distinguished for his learning and public spirit. Its object is to demonstrate the folly of devoting seven or eight years of the life of youth to the "scraping together of so much miserable Latin and Greek as might be learned otherwise easily and delightfully in one;" and also to show that it is practicable to initiate young students into science and language by the same process, making a knowledge of things the immediate result of an acquaintance with words. Milton did not, like some ignorant modern innovators, propose to discard the study of the classics from his plan of education. What he aimed at was far more rational; namely, to economize the expenditure of time, and to combine the learning of languages with the acquisition of some knowledge of logic, rhetoric, ethics, politics, law, theology, criticism, composition, and the elements of the physical sciences, thus rendering the one, as it were, administrative to the other. The plan, as sketched by Milton himself, is perhaps constructed upon too magnificent a scale; indeed it is not a scheme for private individuals to attempt to carry into effect; but an enlightened government, with the vast collegiate resources of England at its disposal, might, without injuring existing establishments, erect in every county an academical institution, as the platform of a system which is unquestionably based upon solid principles. All the recent improvements in education, which can properly be considered as such, more particularly the attempts which have been partially made to combine with the study of the classics the acquisition of useful knowledge, are to a certain extent a practical recognition of the soundness of those principles; and there can be little doubt, we think, that time and experience will show the propriety, if not the necessity, of carrying this combination farther, and rendering it closer and more intimate than has yet been judged expedient by the instructors of youth, a class of men who, however willing to teach, are commonly slow to learn.

But, in point, ability, and eloquence, the *Tractate on Education*, with all its merits, was surpassed by another composition produced about the same time, and addressed

¹ The treatises on divorce are equal to any which Milton ever wrote. Every page is strewn with felicities, and shines with a lustre unsurpassed by himself on happier though perhaps not more interesting themes. He makes out a strong case, and fights with arguments which are not easily to be repelled. The whole context of the Holy Scriptures, the laws of the first Christian emperors, the opinions of some of the most eminent amongst the early reformers, and a projected statute of Edward VI., are adduced by him for the purpose of demonstrating, that, by the laws of God, and by the inferences of the most virtuous and enlightened men, the power of divorce ought not to be rigidly restricted to those causes which render the nuptial state unfruitful, or which taint it with a spurious offspring. Regarding mutual support and comfort as the principal object of this union, he maintains, that whatever defrauds it of these ends, essentially vitiates the contract, and must necessarily justify its dissolution. And, upon the assumption that marriage is nothing more than a mere contract, this reasoning appears to be unanswerable.

Milton. to the parliament under the title of *Areopagitica*, or a *Speech for the Liberty of unlicensed Printing*. The Presbyterians, it appears, on rising into power, speedily forgot the principles which they had professed in adversity; and, declaring against unlimited toleration, discovered, by their readiness to abridge the rights of others, that their tenderness was only for their own. The press was too powerful an engine not to be seized by these selfish monopolists of liberty. Intolerance had now changed its garb and denomination; instead of a cassock and lawn sleeves, it appeared in the plainer attire of a Geneva gown and band; but the essential spirit remained the same. Hence, the very men who had so indignantly complained of restraints on the press, when imposed by the church, lost no time in subjecting it to the most rigorous censorship when it passed into their own hands. They accordingly revived the *imprimatur* of the Star-chamber, and expurgated every book of every word and phrase which accorded not with their taste, or jarred with their peculiar notions. Against this monstrous grievance, the offspring of tyranny and apostasy, Milton advanced as the champion of free discussion; and never was a good cause more powerfully defended. The *Areopagitica* is, beyond all doubt, one of his finest and noblest compositions; admirable in style, irresistible in reasoning, and unsurpassed in eloquence.¹ In fact, its arguments, which are individually strong, derive so much force from their mutual support in a close and advantageous array, as imperiously to compel conviction. But this splendid effort, in which Milton appears to have concentrated all the powers of his great mind, proved unavailing. The Presbyterians were too sensible of the utility of a censorship to be moved by any thing that could be advanced against it, and the powerful reasoning of the *Areopagitica* was urged in vain. If the parliament, however, remained obdurate, the impression produced on individual minds was strong and lasting. Gilbert Mabbot, one of the licensers, resigned his situation, defending his conduct and motives from the work in question; and Cromwell was so moved by it, that during his protectorate he abolished the censorship of the press.

In 1645, Milton prepared an edition of his miscellaneous poems in English, Latin, and Italian, which appeared with the author's name, and a preface by the publisher, Humphrey Moseley. The principal pieces in this collection have already been incidentally noticed; the novelties consist chiefly of sonnets, in which, more perhaps than in any of his other compositions, the peculiar character of Milton is displayed. These remarkable poems have been undervalued by critics who have not understood their real nature. They have neither epigrammatic point nor antithetical contrasts. There is none of the refined ingenuity of Filiaja in thought; none of the hard and brilliant enamel of Petrarch in the style. They are simple but majestic records of the feelings of the poet, expressed with as little apparent effort or elaboration as if they had been set down in his diary. A victory, an unexpected attack upon the city, a momentary fit of exultation or depression, a jest thrown out against one of his own books, a dream that for a moment restored to him the vision of that beautiful face over which the grave had heaped its undistinguishing

mould, all led him to musings which spontaneously arranged themselves in verse. Hence the sonnets are more or less striking, according as the occasions out of which they sprung are more or less interesting. That which he wrote "when the assault was intended to the city," and those addressed to Cyriac Skinner, Fairfax, Vane, and Cromwell, are pre-eminent for loftiness and vigour, and animated with a great and mighty spirit. In fact, they are, almost without exception, dignified by a sobriety, yet greatness, of mind, to which we know not where to look for a parallel. Unity of sentiment and severity of style are the characteristics of them all. In the finishing of such short poems, which solicit ornament from variety of thought, on the indispensable condition of perfect subordination, greater accuracy and elegance might perhaps be expected. But they are all conceived and executed in a grand, broad style, with a freedom and boldness of hand which always bespeaks a master of the art. Like a small statue from the chisel of Lysippus, or a miniature from the pencil of Michel Angelo, they demonstrate that the idea of greatness may be excited in our minds by the least of those works on which genius has stamped its magical impression.²

In 1646, the wife of Milton gave birth to her first child, a daughter, baptized by the name of Anne, who appears to have been lame from her early infancy; and, in the following year, his father died, whilst the Powells left him to return to their former residence in the country. At this period, says Toland, "he revived his academic institution of some young gentlemen, with a design, perhaps, of putting in practice the model of education lately published by himself; yet this course was of no long continuance, for he was to have been, in 1647, made adjutant-general to Sir William Waller, but that the new-modelling of the army, and Sir William turning cat-in-pan, this design was frustrated." In 1648, Milton's second daughter, Mary, was born; and soon afterwards the course of public events introduced him to an honourable and important office in the state.

The political occurrences of this period, in as far as these were connected with the personal history of Milton, have been briefly and lucidly described by Dr Symmons. The victory of Naseby, gained on the 14th of June 1645, by the army under Fairfax and Cromwell, may be considered as having terminated the contest between the king and the parliament. From this time the unhappy monarch was, in truth, in the hands of his enemies, and passed several months in a species of captivity at Oxford. In April 1646, he fled to the army of the Scots before Newark, under the command of the Earl of Leven, by whom he was detained as a prisoner; and not long afterwards he was delivered to the commissioners of the parliament, and by them conducted to Holdenby House in Northamptonshire. Here he remained until June 1647, when he was seized by the army, and, after some removals, settled at Hampton Court. At this crisis, an opportunity was presented him of recovering his fallen fortunes and replacing himself upon the throne. Cromwell and Ireton, uncertain of the result of the contest with the Presbyterians, and apprehensive of a junction between the latter and the royalists, now offered to reinstate him in his kingly dignity, upon certain con-

¹ Some men love to be singular, and thus think themselves original. Sir Egerton Brydges alleges, that as soon as Milton descended from his poetic throne, to take part in the "coarse conflict of practical affairs," the happy delirium of glorious genius subsided into a cold and harsh stagnation of all that was eloquent and generous. (*Life*, p. 66.) Now this writer had either read the *Speech for the Liberty of unlicensed Printing*, or he had not. If he had read it, what are we to think of his judgment as a critic? If he had not, what becomes of his fidelity as a biographer? In 1738, when the freedom of the press was considered in danger, Thomson, author of the *Seasons*, published an octavo edition of this discourse; and, at such a time, he could not possibly have rendered a more acceptable service, as it contains all that can be urged in favour of that species of liberty, without which there is no security for any other. Milton was the first man in this country who asserted the unlimited right of free discussion; the subject called forth all his powers; he viewed it in all its aspects and bearings; he anticipated and refuted the arguments by which his positions might be controverted; and so admirably did he perform his task, that he left almost nothing to be added by others.

² *Edinburgh Review*, vol. xlii. p. 324. Symmons's *Life of Milton*, p. 272.

Milton. ditions, which they stipulated in behalf of themselves and their friends. But the infatuated monarchs rejected the proffers of fortune, and, by his haughtiness, fluctuation, and duplicity, gave mortal offence to the only individuals who had the power to save him. Even at Carisbrooke Castle, where he was confined on his flight from Hampton Court, fortune seemed again disposed to redress her past wrongs, and to give him back by treaty a large portion of what had been ravished from him by force of arms. But his fatal obstinacy repulsed her advances, and this, added to his perfidy, sealed his doom. He refused with scorn the proposals of the army, thinking to prevail by means of the different factions, and to regain by policy what he had lost in fight. All hopes of accommodation had thus vanished. The nation was torn in pieces by contending factions, each desirous to employ the king as an instrument for attaining its own objects. How to dispose of him now became the only question, and it was speedily decided. The army demanded his death, which its leaders deemed indispensable to their own safety; the Presbyterians in the parliament, who would have joined the king against the army, were seized and committed to prison; the unfortunate monarch, after the semblance of a legal trial, was condemned to suffer death; and on the 30th of January 1648-49, he was executed, in pursuance of the sentence passed upon him, for having "traitorously and maliciously imagined and contrived the enslaving or destroying of the English nation."

Hitherto Milton had remained an inactive spectator of events; he had taken no part in the controversy in which the king, the parliament, and the army were engaged; and he had been in no way accessory to the king's death. Now, however, his services were required in behalf of those who had been principally concerned in that distressing transaction; and, in February 1648-49, he published *The Tenure of Kings and Magistrates*, in which he attempted to prove "that it is lawful, and hath been held so through all ages, for any who have the power, to call to account a tyrant or wicked king, and, after due conviction, to depose and put him to death, if the ordinary magistrate have neglected or denied to do it." This work, he tells us, "was written rather to tranquillize the minds of men, than to discuss any part of the question respecting Charles," the discussion of which belonged to the magistrate and not to him, and which had already received its final determination. He also disclaims having directed his argument or persuasion against Charles personally; contenting himself with proving, by the testimony of many of the most eminent divines, "what course of conduct might lawfully be observed towards tyrants in general." The subject, in fact, is discussed without any taint of virulence or acrimony, with much force of reasoning, and a considerable but not an ostentatious display of learning. That kings and magistrates are amenable to the laws, and may be punished for the violation of them, is argued from the origin and constitution of society, from the authority of the Jewish scriptures, from that of the most eminent Christian divines, and from the practice of all civilized nations; and the author has unquestionably demonstrated, that the responsibility of kings to a human tribunal is a doctrine which has not been considered as incompatible with Christian theology. If this were not so, then the doctrine that tyrants may lawfully be resisted, could no longer be maintained; for, to make resistance lawful in any circumstances, the tyrant who abuses his power and tramples down the rights and liberties of the people, must first of all be held to be responsible, not to God only, but to the nation whose laws he has violated. But it may, nevertheless, be doubted whether the authorities produced by Milton support, to its full extent, the assertion in the title of this work, "that it is lawful for any who have the power to call to account

a tyrant;" even although the assertion be somewhat qualified by the subsequent words, "and, after due conviction, to depose and put him to death." It is much more easy to establish the responsibility of tyrants generally, than either to define its limits, or to fix the jurisdiction by which it may be rendered effectual.

Milton's next work was *Observations upon the Articles of Peace between Ormond and the Irish Rebels*, signed at Kilkenny on the 17th of January 1648-49. One of the principal causes of the king's misfortunes and ruin was his supposed connection with the Irish Catholics; and the treaty concluded with them by his representative, at the time here mentioned, served to confirm public prepossession on the subject. The rebellion in Ireland had been distinguished by circumstances of peculiar atrocity, all evincing the power of long-continued oppression to debase and unhumanize the hearts of men. Mercy seemed to have fled from the earth; cruelty exhausted its horrid and sickening refinements; enormities, which admit not of description, were perpetrated; all ordinary ties were disregarded; no voice was listened to, save that of revenge. Never, even in the annals of servile wars, had the wild passions of infuriated slaves rioted in more indiscriminate slaughter. Yet in the massacre itself the king had no participation; it was the terrible, but not necessary nor foreseen consequence of the revolt; and Charles can only be held as having been accessory to the rising, by considering his sanction as implied in that of the queen, and from the circumstance that the leaders of the insurrection everywhere professed to act under the royal authority. But, in the first place, so grave an imputation should not be made on grounds of constructive probability alone; and, secondly, it seems to be now admitted on all hands that the king's commission, pretended by O'Neale, was a forgery of his own. The opportunity, however, was too favourable to be neglected by Milton; and he found little difficulty in exciting indignation against the articles of a peace which, abandoning the English and Protestant cause in Ireland, permitted its enemies to exult in the success of their sanguinary vengeance.

Milton now retired for a time from the field of political warfare, and, reverting to the more peaceful occupations of literature, composed four books of a *History of England*, which he intended to consecrate to the honour of his native country. But the prosecution of this undertaking was suspended by an event which formed a remarkable epoch in the life of the poet; namely, his appointment as Latin secretary to the council of state. His profound knowledge of the Latin language, in which the council had determined to carry on all their correspondence with foreign nations, and the elegance of his style, added to his extensive knowledge of history, and other qualifications, pointed him out to the sagacity of the council as a person eminently fitted for such an office; and, accordingly, without even a suspicion of the preferment intended for him, he was invited to enter into the service of the state. The appointment was made on the 15th March 1649, and he immediately applied himself to the duties of his new avocation. It has been suggested, with some appearance of probability, that he must have been indebted for this preferment either to the younger Vane or to Bradshaw, who were members of the council, and who have been made the subjects, both in prose and in verse, of his eloquent and poetic panegyric. But if the preference was, in the first instance, the suggestion of friendship, it was afterwards proved by the event to have been the dictate of wisdom. The hand of the Latin secretary most ably concurred with the spirit of the executive council; and during his continuance in office, which was prolonged till the Restoration, the state papers in his department may be regarded as models of diplomatic composition. Amongst the correspondence of Milton,

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Milton. during the protectorate of Cromwell, were a series of letters addressed to the kings of France, Denmark, and Sweden, relative to the persecution of the Vaudois, which might be cited in proof of what has just been stated. The official instruments were no doubt faithful to the general purposes of the man who then governed England; but they also exhibit much of the liberal and benevolent spirit of the secretary; and, by their dignified yet conciliating tone, strong reasoning, and persuasive eloquence, they deserve to be classed amongst the ablest compositions of the kind to be found in any language. Nor was it merely in conducting the correspondence of the state with foreign powers that Milton's ministerial agency was employed. It appears to have been used by the council in all cases which related to foreigners, and to have been nearly of an equal extent with that of the modern secretary of state for the foreign department. But his pen was not confined to the writing of government despatches or official correspondence.

Soon after the king's death, a book, purporting to have been written by the "royal martyr" himself, appeared, under the title of ΕΙΚΩΝ ΒΑΣΙΛΙΚΗ, or *Portraiture of his Sacred Majesty in his Solitudes and Sufferings*, and made a powerful impression upon the public mind, to the disadvantage of the republican cause. The fate of the unhappy Charles had very generally excited strong feelings of sympathy. He appeared to have been the victim of an ambitious and sanguinary faction; and, whilst his faults were generously buried in his grave, his virtues were aggrandised by pity for his misfortunes, and honoured with exaggerated commendation. Hence the appearance of a work, professedly by his own hand, in which he is represented in the constant exercise of prayer, asserting the integrity of his motives before the great Searcher of Hearts, and urging a fervent appeal from the injustice and cruelty of man to the justice and clemency of God, was eminently calculated to agitate the public mind in his favour, and to make every tongue vibrate in execration of his enemies. To counteract the effect of this popular production, which threatened to become alarmingly great, the council determined to avail itself of the abilities of its new secretary, and delegated to Milton the task of contending with the *Eikon Basiliké*. This he performed with singular ability, in his *Εικονοκλαστής*, or Image-breaker, the title prefixed to this refutation of the reputed work of royal authorship, and which may be regarded as one of the most finished and powerful of his controversial productions. There does not appear to have been any order in council directing him to write this

Milton. answer; but his own words are full and express as to the direction he had received. "A book appeared soon after," says he, "which was ascribed to the king, and contained the most invidious charges against the parliament. I was ordered to answer it, and opposed the *ICONOCLAST* to the *IKON*." It is certain that the royalists depended greatly on the effect which they expected to be produced by the *Eikon Basiliké*; forty-seven editions of it were circulated in England, and forty-eight thousand five hundred copies are said to have been sold. Milton, therefore, felt that the peace and safety of the commonwealth were at stake, and having entered into his subject with his usual ardour, he completed his task with even more than his ordinary success.

The genuineness of the *Eikon* long remained a matter of controversy; but all doubt upon this subject has for some time been set at rest. It is now certain that the use of the king's name was a fraud, and that the real author of the book was Gauden, bishop of Exeter. This has been established by evidence so convincing and conclusive, that the question may be considered as definitively settled.¹ From several passages in the *Iconoclast*, it is evident that Milton strongly suspected the *Eikon* to have been the production of some "idle and pedantic" churchman; but it seems to have been his policy to permit the imposture to pass, and to deal with the work as if it had been the genuine effusion of the royal personage whose name it bears. Pressing closely on his antagonist, and tracing him step by step, he either exposes the fallacy of his reasonings, or the falsehood of his assertions, or the hollowness of his professions, or the convenient speciousness of his devotions. He discovers a quickness which never misses an advantage, and a keenness of remark which carries an irresistible edge. In argument and in style the *Iconoclast* is equally masterly, being at once compressed and energetic, perspicuous and elegant. It is a work, indeed, which cannot be read by any man, whose reason is not wholly under the dominion of prejudice, without producing a conviction unfavourable to the royal party; and it justly merited the honourable distinction conferred upon it by royalist vengeance, of burning in the same flames with the *Defence of the People of England*.² The *Iconoclastes* was first printed in 1649; a second edition of it appeared in the following year; and, in 1652, it was again published in London by Du Gard, in a French translation. It received two answers; one with the title of *Εικων ἀκλαστος*, or the Image Unbroken, in 1651; and the other, called *Vindiciæ Carolinæ*, in 1692.

¹ See on this subject, *Who Wrote Eikon Basiliké?* by Dr Christopher Wordsworth, London, 1824; and more especially a most masterly discussion of the same question in the *Edinburgh Review* (vol. xlv. p. 1, et seq.) by Sir James Mackintosh, one of the ablest and most conclusive pieces of historical reasoning and investigation to be found in modern literature.

² Dr Johnson, who misses no opportunity of libelling the character of Milton, accuses him of having interpolated "the book called *Eikon Basiliké*, by inserting a prayer taken from Sidney's *Arcadia*, and imputing it to the king." One would have thought that the very severity with which Milton, in one passage of his work, has animadverted on the king for having adopted this prayer, and given it, with a few immaterial alterations, as his own to the bishop who attended him on the scaffold, might have saved his memory from the imputation of an act at once so scandalous and so paltry. But, fortunately, we possess the most satisfactory evidence of his entire exemption from the dishonest meanness imputed to him. It was by Royston, who is said to have received the manuscript from the king, and not by Du Gard, the printer of the parliament, that the edition of the *Eikon* was printed in which the controverted prayer originally appeared; and, surely, Royston's royalist press was remote from the suspicion of any contact with Milton or his supposed accomplice Bradshaw. Yet with this fact staring him in the face, Dr Johnson admitted the calumny, which the infamous Lauder had revived, and attempted to affix on the name of Milton the stigma of forgery. The first edition of the *Eikon Basiliké*, to which this prayer, called "a prayer in time of captivity," is attached, was printed for R. Royston, at the Angel in Ivy-lane; a fact which utterly annihilates the charge, whilst it proves the "malice" in which it originated. "Faction," says Johnson, "seldom leaves a man innocent, however it might find him." The maxim is not only true, but its truth has been exemplified by its author, whose guilt, in this particular, Dr Symmons has unanswerably exposed. (See *Life of Milton*, pp. 328, 329, et seq.)

This is no new charge. It was originally broached by Lauder in his publication entitled *King Charles Vindicated from the charge of Plagiarism brought against him by Milton, and Milton himself convicted of Forgery and a Gross Imposition on the Public*, which appeared in 1754, some time after his forgeries in regard to the *Paradise Lost* had been detected and exposed by Dr Douglas, and after he had publicly confessed his guilt in a penitential letter addressed to that eminent person. The dog returned to his vomit again, and invented this new falsehood in the hope of attracting some attention by a fabrication which it might be difficult to refute. But he was deceived in his expectation. The "unsuspicious falsehood" failed to obtain that degree of regard which was requisite to render it of any use to the author; yet, "with a notable and hardy contempt of truth," it was afterwards revived by Johnson, "the great literary patron of Lauder," and his accomplice in the infamous but abortive attempt to blast the reputation of Milton. (Symmons' *Life of Milton*, App. pp. 627, 628.)

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We may mention here, that on his appointment to the office of Latin secretary, Milton removed, in the first instance, to a lodging in the house of one Thompson, at Charing-cross, and afterwards to apartments in Scotland Yard, where his wife gave birth to her third child, a son, who died in infancy, on the 16th of March 1650. And in 1652 he shifted his residence to Petty France, where, till the period of the Restoration, he occupied a handsome house, opening into St James's Park, and adjoining to the mansion of Lord Scudamore.

But, wherever his dwelling-place might be, he was destined to enjoy no respite from labour. No sooner had he finished his masterly reply to the posthumous work (as it was then generally considered) of King Charles, than he was again called upon to enter the lists as the assertor of the commonwealth of England; but he was now to be opposed to a more formidable antagonist, and to contend on a far more ample field. His refutation of the *Eikon* had been confined almost within the limits of his own country. But in the contest in which he was about to engage, the powers of his mind were to be exhibited to Europe at large, and the whole family of civilized nations were to witness his victory or defeat. Charles II. was at this time protected by the states of Holland, and being anxious to appeal to the world against the execution of his father, as well as to blend his own with the general cause of kings, he employed Claudius Salmasius, or Claude de Saumaise, then an honorary professor in the university of Leyden, to write a defence of the late king and of monarchy. This man, who was famed for his learning, and held a high rank amongst the most eminent scholars of that age, had already distinguished himself by the publication of a book in defence of civil and religious liberty; and, as the reward of his exertions, he had received the grant of a pension from the republic of Holland. It would have been well for Salmasius had he been content to enjoy the advantages of his lot in the bosom of tranquillity, and had he refused to tarnish his reputation, belie his principles, and compromise his peace, at the solicitation of an intriguing and profligate prince. But when a king sued to be his client, and the cause of sovereigns claimed the support of his pen, his vanity overmastered every other consideration; in an inauspicious hour he undertook the defence of prelacy, monarchy, and Charles I.; and, in virtue of this engagement, he produced his *Defensio Regia pro Carolo Primo ad Carolum Secundum*, which made its appearance before the close of the year 1649.

This book, taken as a whole, greatly disappointed the expectations of the learned. With the tenacious memory, the quick combination, and the acute microscopic vision, of the scholar and the critic, its author was destitute of that grasp and comprehension of mind which are requisite for the discussion of complex political systems. Throughout the whole of the Royal Defence there is a pervading littleness, of which the reader is soon rendered painfully sensible. Its author, like Martha, is troubled about many things, and seems overwhelmed with trifles. Etymology is frequently substituted for argument; quotations are accumulated without judgment or felicity; and his materials are put together without method, unassorted and unarranged. Still, the Royal Defence is by no means a contemptible production. It amasses nearly all that can be collected on the subject; in its management it is sometimes skilful, as in its execution it is occasionally happy; and it presents us with argu-

ments which are often subtle and generally specious. "But the circumstance which will principally recommend this work of Salmasius's to a numerous party in the present day," observes Dr Symmons, "is the vivid recollection which it forcibly awakes, of some of the political writings Mr Burke. The same dark arsenal of language seems to have supplied the artillery which, in the seventeenth century, was aimed at the government of England, and in the close of the eighteenth at that of France; and many of those doctrines which disgust us with their naked deformity in the Leyden professor, have been withdrawn from our detestation under an embroidered and sparkling veil by the hand of the British politician. When Salmasius calls upon the monarchs, and indeed upon all the well-instituted republics, or, in other words, the regular governments of Europe, to extirpate the fanatic and parricide English, the pests and the monsters of Britain, we must necessarily be reminded of Mr Burke's crusading zeal against the revolutionists of France, and be persuaded that he blows the trumpet bequeathed to him by the antagonist of Milton, and sullied with the venal breath which was once purchased by Charles. Unquestionable resemblance is to be discovered in the Royal Defence to those pieces of Mr Burke's which respect the French revolution; and if the former were to be translated, the English reader would be less struck with the novelty of the latter, and more disposed to assent to what was asserted by the wise man more than three thousand years ago, that 'there is now no new thing under the sun.'"¹ On the causes of this resemblance we shall not venture to offer any opinion. Similar thoughts might be suggested by similar subjects; the same passions, however excited, might naturally rush into the same channel of intemperate expression; or the discursive mind of Burke might range even the moors of Salmasius to batten on their coarse produce, and, finding them replenished with bitter springs, might be induced to draw from them supplies to feed the luxuriancy of his own invective.

But whatever might be the intrinsic merit of the Royal Defence, it derived importance from the name of Salmasius; and the appeal being made to all Europe, especially to crowned heads, it was not likely to be without its effect. The council of state immediately perceived the necessity of replying to it, and it was accordingly resolved "that Mr Milton do prepare something in answer to the book of Salmasius, and when he hath done it, bring it to the council." This entry is dated the 8th January 1649-50; and there is another, dated the 23d of December 1650, in which it is ordered "that Mr Milton do print the treatise which he hath written, in answer to a late book written by Salmasius, against the proceedings of the commonwealth." By this time his sight had become greatly impaired, and he was forewarned by his physicians that the total loss of it would be the infallible result of his labour; but, undeterred by this prediction,² and unrestrained by bad health, which allowed him to compose only at intervals, with hourly interruptions, he persevered in the work which he had undertaken, and produced, early in 1651, that noble acquittal of his engagement to the council, the *Defensio pro Populo Anglicano contra Claudii Salmasii Defensionem Regiam*. This work more than answered the expectations which were entertained of it. Indeed the triumph of Milton was decisive, and the humiliation of his adversary complete. It would be difficult even for its greatest ad-

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¹ Symmons' Life of Milton, pp. 357, 358, 359.

² "I would not," says he, "have listened to the voice even of Esculapius himself, from the shrine of Epidaurus, in preference to the suggestions of the heavenly monitor within my breast; my resolution was unshaken, though the alternative was either the loss of my sight or the desertion of my duty." "I considered," he adds, "that many had purchased a less good by a greater evil, the meed of glory by the loss of life; but that I might procure a great good by a little suffering; that though I am blind, I might still discharge the most honourable duties, the performance of which, as it is something more durable than glory, ought to be an object of superior admiration and esteem." (Second Defence, *Prose Works*, p. 927.)

Milton. mirer to speak of this masterly composition in terms of too high commendation. "If happily," says Dr Symmons, "it had been less embittered with personal invective, and had withdrawn the two immediate combatants to a greater distance from our sight; if it had excluded every light and sportive sally from its pages, it would have approached very nearly to perfection, and would have formed one of the most able and satisfactory, the most eloquent and splendid, defences of truth and liberality against sophistry and despotism, which has ever been exhibited to the world." Its diction is pure, spirited, and harmonious;¹ the language of Cicero is upon the author's tongue, "winged with red lightning and impetuous rage;" and through this appropriate medium are conveyed strong argument, manly sentiment, comprehensive erudition, and profound wisdom, relieved at intervals by sallies of excursive fancy. By the laws of God, either written in the heart of man or made the subject of immediate revelation, and by the testimony of all history, sacred and profane, the Defence of the People of England shows that political power properly emanates from the people, that for their benefit it must be exercised, that for their good it may rightfully be resumed. With reference to the point more immediately at issue, the author asserts the ancient genealogy of English freedom, and traces it from its British origin, through its Saxon and Norman lineage, down to the establishment of the commonwealth. During the whole of this period he proves that the existence of the ultimate sovereignty of the people was established by solemn acts, or by acknowledgment in compacts; and, from the Saxon times, he demonstrates the existence of a supreme legislative assembly, by which the conduct of the executive was controlled, and to which the chief magistrate was responsible. He is unquestionably too severe in his treatment of Charles, and we are fatigued with the perpetual recurrence of invective against his antagonist; but the one was provoked by exaggerated praise, and the other may find some excuse in the abusive and insolent language with which the government and people of England had been assailed. He condescended to fight the adversary with his own weapons, and answered a fool according to his folly.

The Defence of the People of England was received and read with universal applause and admiration; and, whilst the production of his opponent crept languidly through a confined circulation, it passed rapidly through several impressions,² was translated into foreign languages, and occupied a large space in the public mind. Even Christina, queen of Sweden, is said to have commended it openly, although, from her rank and character, she could scarcely be supposed to have any great favour for its doctrines. The result of the contest was peculiarly affecting to the feelings and unfavourable to the interests of Salmasius. The Swedish queen frowned upon him as a pernicious parasite; the states of Holland suppressed his work, as one calculated to promote tyranny; and the numerous

enemies whom his want of moderation had excited, exulted openly in his fall. It has been asserted that the various mortifications which he experienced on this occasion proved eventually fatal to his life; and it is not improbable that wounded pride and vanity might prove injurious to health, and accelerate the crisis of dissolution. He retired from the court of Stockholm in September 1651, and the following year died at Spa in Germany, just after he had completed a most virulent reply to his opponent, on whose devoted head he accumulated every crime which his malignity could invent, and heaped every opprobrious epithet which a copious vocabulary of abuse could supply. It is stated by Toland, and repeated by others on his authority, that Milton received £1000 from the Treasury as a reward for this great work. That he deserved recompense no one can doubt; but there is reason to believe that Toland had been misinformed; for, in the Second Defence, published three years afterwards, he declares that he had "not been made one penny richer" by the publications he had undertaken for the service of the country.³ He received the thanks of the council "for his good services," which they seem to have duly appreciated; but the terms in which these are conveyed seem to indicate that this was the only acknowledgment.⁴ His best reward, however, was the triumphant success with which he vindicated the people of England, and annihilated the presumptuous foreigner who had been hired to calumniate them.

In 1652, Milton, having removed from his lodgings in Whitehall to a house opening into St James's Park, lost his wife in child-bed, and was left with three motherless daughters, in domestic solitude, and in a state of almost total blindness. The prediction of his physicians had been but too fatally verified. His sight, naturally weak, had for several years been declining; and the composition of his last great work had completed its extinction. In the course of this honourable labour he lost entirely the vision of one eye; that of the other soon afterwards closed; and "for the book of knowledge fair" he was "presented with an universal blank of Nature's works." But such was the vigour of his intellect, that, in addition to the discharge of his duties as secretary to the council, he continued his labours in defence of the commonwealth. His mind was too eager to be diverted from his purpose, and too strong to be subdued even by this accumulation of calamities. The precise date of his blindness, however, has not been ascertained; and equally unfixed is that of his second marriage, which appears to have taken place about two years after his entire loss of sight. The lady whom he chose on this occasion was Catherine, daughter of Captain Woodcock of Hackney, who seems to have been the object of his fondest affection. Like her predecessor, she died in child-bed within a year after her marriage, and the daughter she bore to him soon followed her to the grave.

Numerous replies to Milton's Defence of the People of England were sent forth by the royalists, but these he left

¹ Hobbes, speaking of the combatants, declares himself unable to decide whose language was best, or whose arguments were worst. Johnson thinks that "Milton's periods are smoother, neater, and more pointed." As to the arguments of Salmasius, it is a strong presumption against them, that Hobbes, with all his acuteness, added to his known partiality for despotism, could find nothing to say in their favour.

² The author of the *Clamor Regii Sanguinis ad Cælum*, which called forth the Second Defence, says, "Of what the execrable Milton has spitefully elaborated to ruin the reputation of the deceased king, and to destroy the hereditary succession to the crown, there are so many editions, that I am uncertain to which of these I should refer my readers."

³ Tuque scito illas "opimitates" atque "opes," quas mihi exprobras, non attigisse, neque eo nomine, quo maxime accusas, obolo factum ditiores.

⁴ Dr Symmons conjectures that the munificence of the council might have been posterior to the date of the Second Defence, or that the passage may be regarded as not sufficiently explicit to be admitted against the positive assertion of Toland, coinciding with the general character of the republican government. But, in the first place, as three years confessedly elapsed without the council bestowing on him any special pecuniary recompense, it is scarcely probable that they would do so at a posterior date; secondly, the assertion of Milton is as positive as that of Toland, to which it is in direct opposition; and, thirdly, as secretary of the council, he was a public servant, all of whose energies were fairly exigible for the service of the state.

Milton. to perish in their natural obscurity.¹ In 1652, however, there appeared at the Hague a work entitled *Regii Sanguinis Clamor ad Cælum adversus Parricidas Anglicanas*, which, from the calumnies it heaped both upon the parliament and upon Milton himself, the latter considered as calling for a reply. The real libeller was a Frenchman of the name of Du Moulin, afterwards prebendary of Canterbury; but, fearful of avowing a production calculated to expose him to literary vengeance, he sent it in manuscript to Salmasius, by whom it was consigned, for the purpose of publication, to one Alexander Morus or More, a man of Scotch parentage, but settled in France, and at this time principal of the protestant college of Castres in Languedoc, where he had acquired some celebrity as a preacher. Morus readily undertook the honourable task proposed to him, wrote a dedication to Charles II. under the name of the printer,² and became so mixed up with the work, that, until Du Moulin was compelled to acknowledge his production, he was generally considered as its author. But he had reason to repent bitterly the part he acted in this disgraceful action. For a brief and equivocal reputation (of which he made the most whilst it lasted), his life was embittered, and his memory covered with infamy. A terrible castigation awaited him. In 1654, Milton produced his reply, under the title of *Defensio Secunda pro Populo Anglicano, contra infamem Libellum anonymum cui titulus "Regii Sanguinis Clamor ad Cælum."*

In answer to the slanders with which his adversary had attempted to overwhelm him, he found it necessary to give a sketch of many parts of his own history, and to disclose the motives and springs of action by which his conduct had been regulated; a delicate task, in the execution of which he speaks with the confidence of innocence and the unfaltering dignity of truth. On this account the work is peculiarly interesting, and has supplied his biographers with materials, which are of the more value as they cannot be obtained any where else, and their authenticity is beyond all doubt. The defensive portion of the work, therefore, is that which at present constitutes its principal interest. But at the time of its publication, the attraction consisted in its active and unsparing hostility. The character of Morus was, unhappily for himself, not proof against attack. Of a quarrelsome and overbearing temper, he was at variance with every body; whilst his uncontrolled attachment to women involved him in adventures not calculated to reflect much credit upon a minister of the gospel. Possessing correct information as to his conduct, and resolved to use it without scruple, Milton pursues him through the opprobrious privacies of his immorality,³ and exacts a severe vengeance for those savage insults, in the guilt of which he had become implicated as a party and an accomplice. Morus struggled to support himself by a reply, which Milton demolished in another answer; as he did also a second attempt of the same kind in a short confutation, which terminated the controversy. In the course of it the sufferings of Morus had induced him to give up the author of the publication which had brought upon him such a fearful visitation; and Du Moulin, who was then in England, felt himself to be in danger; but, for some reason or other, Milton suffered the Frenchman to escape chastise-

ment. It is probable enough, as Dr Symmons suggests, that, regarding Morus and his associate "as joint parties in a bond, he conceived himself to be justified in calling upon the most responsible of the two for the payment of his debt."

But, independently of its communications respecting its illustrious author, the Second Defence contains many striking passages, and exhibits a variety of entertaining matter. It introduces to our notice many of the writer's republican friends, as Fleetwood, Lambert, Howley, Merton, Whitelocke, Pickering, Strickland, Sydenham, Sydney, Montacute, Laurence, Fairfax, and Bradshaw; and, besides an animated address to Cromwell, in which the character of that remarkable man is ably portrayed, it presents us with an eloquent eulogy on Christina, queen of Sweden, in requital, as it would seem, of the praise which the daughter of the great Adolphus had so liberally bestowed on his Defence of the People of England. Of the address to Cromwell, Johnson observes, in his characteristic manner, that "Cæsar, when he assumed the perpetual dictatorship, had not more servile or more elegant flattery." The beauty of the composition, indeed, has never been, and cannot be, disputed; and as to the alleged "servility," they alone can properly judge who are capable of appreciating the wisdom of the advice which is tendered to the protector, in connection with the state of affairs at the time when Milton wrote. The Long Parliament had been dismissed; its successor, nicknamed Barebones' Parliament, had also been dissolved; and the captain-general, with his military council, found himself in possession of a kind of derelict sovereignty. On the 16th of December 1653, Cromwell was installed into the office of Lord Protector of the Commonwealth of England, and under that title now possessed the supreme power. Some provision appears to have been made for convening a triennial parliament; but the country was torn in pieces by contending factions, and the only hope of the restoration of internal tranquillity depended on the honesty and firmness of the protector, whose wisdom and courage had already, on more than one occasion, proved the salvation of the commonwealth. Milton, whose address appears to have been composed immediately after Cromwell's elevation, could not be unconscious of the egregious mockeries which had been practised upon the people, or insensible to the danger with which liberty was threatened by the concentration of all the powers of the state in the person of the protector; but still it was natural for him not to abandon, without extreme reluctance, the hopes which he had cherished respecting the protector's rectitude of intention; and hence he seems desirous of urging him to a just and generous exercise of power by every motive which wise counsel or eloquent panegyric could suggest. Milton was not a venal parasite or a courtly flatterer. He certainly approaches the master of England with elevated sentiments, and in elegant language extols the enlightened wisdom, martial prowess, and stern integrity, by which the conduct of that fortunate soldier had hitherto been characterized; but extravagant as some of his praises may now be thought, it cannot be denied that, even in these, he discovers the quality of an erect and independent spirit.⁴

¹ The earliest of these replies, all of which were anonymous, was erroneously imputed to Bishop Bramhall. It appeared in 1651, with the strange title of *Apologia pro Rege et Populo Anglicano contra Joannis Polypragmitici, alias Miltoni Angli, Defensionem destructivam, &c.*

² Adrian Ulac, in Latin *Vlaccus*.

³ The following epigram, commonly attributed to Milton, relates to one of the licentious amours in which Morus had been engaged:—

Galli ex concubitu gravidam te, Pontia, Mori
Quis bene moratam raorigeramque neget?

On this point of attack, Morus, in his reply, gave his antagonist an advantage, by inadvertently correcting the orthography of the girl's name, which, he affirmed, ought to be written *Bontia*, and not *Pontia*.

⁴ The conduct of Milton during the administration of the protector is a subject on which his enemies delight to dwell. "That

Milton.

With the Second Defence of the People of England, and the two subsequent replies to Morus, Milton closed his controversial labours. He still continued to serve his country in the character of Latin secretary; but his disapprobation of the actual state of affairs is evident from more than one of his letters; and he seems to have acquiesced in the existing evil only because it was irremediable, and inferior in degree to the calamity of a restoration. Mortified and disappointed, he now sought relief from the feelings which oppressed him by engaging in the prosecution of three great works; his *History of England*, of which he only completed two additional books; his *Thesaurus Linguae Latinae*; and his immortal epic poem of *Paradise Lost*. Of the History it is only necessary to remark, in addition to what has already been stated, that, prior to its publication in 1670, it was mutilated by the caprice of the licenser, who struck out one of its most spirited and brilliant passages; that the portion expurgated was printed separately in 1681; and that it was afterwards restored to its proper place in the edition of the author's prose works published in 1738. The *Thesaurus*, for which he had made large collections, was never published; but the materials which he had amassed, occupying in manuscript three large folio volumes, were presented by his nephew Philips to the editors of the Cambridge Dictionary, by whom they appear to have been used in the preparation of that work for the press. "To collect a dictionary," says Johnson, "seems a work of all others the least practicable in a state of blindness, because it depends upon perpetual and minute inspection and collation. Nor would Milton probably have begun it after he had lost his eyes; but having had it always before him, he continued it 'almost to his dying day.'" This work indeed appears to have formed a part of that change of literary labour in which he delighted; and it is curious in another point of view, as showing that his mind, with all its energies, could instantaneously pass from invention to compilation, from the glorious visions of fancy to the dry and sterile drudgery of mere verbal collation. As to the third object upon which his powers were at this time exerted, his immortal epic, we shall forbear adverting to it until the time of its completion and publication.

In this variety of vigorous and effective intellectual exertion did Milton employ his leisure hours during the remainder of the protectorate. He was evidently dissatisfied with the state of public affairs; but fearing lest he might aggravate existing evils by any symptom of alienation, and unwilling to break with the protector, in whom his confidence was not yet entirely destroyed, he repressed his feelings, and waited in expectation of better times. In 1655 he composed the manifesto issued by the protec-

tor to justify his war with Spain; and in 1657 Andrew Marvell was associated with him in the office of Latin secretary. In 1658 he published, under the title of *The Cabinet Council*, a manuscript of Sir Walter Raleigh's, consisting of aphorisms on the art of government. But from this and other occupations his mind was soon called to circumstances of an afflicting and embarrassing kind.

In the September of this year, Cromwell, broken down by the cares and anxieties of government, finished his splendid but unenviable career. He died surrounded by difficulties which even his powerful mind knew not how to surmount; suffering acutely under domestic calamity; and leaving the nation a prey to the violence of factions which his vigorous authority alone had for a time restrained. His successor in the protectorate, Richard Cromwell, was not a pilot able to weather the storm now gathering; and at the end of nine months he resigned his perilous office, descending without regret to the safe level of a private station. The council of officers then summoned the relics of the Long Parliament to re-assume the guidance of the commonwealth; but the contests between them and the army ruined the last hopes of the friends of liberty, and introduced a species of anarchy which threatened the setting up of a military despotism. The Presbyterians, taking advantage of these events, now openly avowed their disaffection to the ruling powers, and united themselves heartily with the royalists. This extraordinary conflict of parties, and the confusion which ensued, opened a field to Monk, then governor of Scotland, for the display of his inconstancy, cunning, and perfidy. Favoured by his situation, and solicited at once by the Presbyterians, the people, and the parliament, he was enabled to betray all who confided in him, to abandon his old associates to the butchery of legal vengeance, and to surrender the nation, without a single stipulation in its favour. Never was a counter-revolution effected by such accumulated dissimulation, treachery, and perfidy; never did the liberties of a nation sink under the temporary ascendancy of a meaner, a baser, or a more unprincipled traitor, than the man by whom the Restoration was achieved.

Whilst these events were passing, in the space between the protector's death and the return of Charles, the mind of Milton must have been agitated with severe disquietude. He had seen the structure of liberty which his ardent imagination had erected, dissolve like a vision into air, leaving not a trace or vestige behind. All that was good, or prognostic of good, had passed away; and he now saw nothing but the selfishness of faction triumphing over the rights and the patience of the nation, and precipitating the cause which it professed to support into irretrievable ruin. At this crisis, when England had need of him, Milton was not

an enthusiastic votary of liberty," says Mr Macaulay, "should accept office under a military usurper, seems, no doubt, at first sight, extraordinary. The ambition of Oliver was of no vulgar kind. He never seems to have coveted despotic power. He at first fought sincerely and manfully for the parliament, and never deserted it till it had deserted its duty. If he dissolved it by force, it was not till he found that the few members who remained after so many deaths, secessions, and expulsions, were desirous to appropriate to themselves a power which they held only in trust, and to inflict on England the curse of a Venetian oligarchy. But when thus placed by violence at the head of affairs, he did not assume unlimited power. He gave the country a constitution far more perfect than any which had at that time been known to the world. He reformed the representative system in a manner which has extorted praise even from Lord Clarendon. For himself he demanded indeed the first place in the commonwealth; but with powers scarcely so great as those of a Dutch stadtholder or an American president. He gave parliament a voice in the appointment of ministers, and left to it the whole legislative authority, not even reserving to himself a veto on its enactments. And he did not require that the chief magistracy should be hereditary in his family." (*Edinburgh Review*, vol. xlii. p. 355.) If Cromwell's moderation had been met in a corresponding spirit, there is no reason to think that he would have overstepped the line which he had traced for himself. But when he found that his parliaments questioned the authority under which they were called together, and that he was in danger of being deprived of the limited power he had reserved to himself, then it must be acknowledged that he adopted a more arbitrary policy.

In judging of the conduct of Milton, due regard must be had to the character and circumstances of the times. A good constitution is infinitely better than the best despot. But, at the period in question, the violence of religious and political animosities rendered a stable and happy settlement next to impossible. The choice lay not between Cromwell and liberty, but between Cromwell and the Stuarts. Cromwell was evidently laying, though in an irregular manner, the foundations of an admirable system of liberty. The Stuarts, if restored, would have re-constituted the despotism which had been overthrown. That Milton, therefore, made a wise election no one can doubt who compares the history of the protectorate with that of the thirty years which succeeded it, the darkest and most disgraceful period in the annals of England. (*Edinburgh Review*, *ubi supra*.)

Milton.

Milton. wanting to his country. Apprehensive of returning intolerance, he published two treatises, devoted to the consideration of two opposite evils. One of these was entitled *A Treatise on the Civil Power in Ecclesiastical Causes*; and the other, *Considerations touching the likeliest Means to remove Hirelings out of the Church*. Both these works are written with beautiful simplicity and earnestness, and should be studied by all who wish to understand the principles of religious liberty. In the first of them, he asserts the entire liberty of conscience, and, by arguments drawn from the sacred writings, demonstrates that, in matters purely religious, the interference of the magistrate is unlawful. In the second, he allows the propriety of a maintenance for Christian ministers; but, denying the divine right, as well as the political expediency, of tithes, he contends that pastors ought to be supported by the contributions of their own immediate flocks. In short, the immortal author of the *Paradise Lost* here advocates what, in the language of the present day, is called the voluntary principle.¹

The current of national opinion was now running strongly in favour of monarchy. Harassed by the conflict of parties, and the disorders thereby occasioned, the people were in a state of mind favourable to the projects of Monk, and, regarding the restoration of the kingly power as a less evil than the frightful state of anarchy which now prevailed, were prepared to join him in setting up the old form of government. The earnest protestations of Monk, and the existence of a parliament in which the royalists formed an inconsiderable party, still supported the hopes of the republicans; but Milton, fully aware of what was passing around him, and indignant at the outrages committed by the army, discovered his serious apprehension of the general result, in a letter to a friend, dated the 20th of October 1659, in which he plainly hinted his suspicions of Monk, whom circumstances had rendered the arbiter of his country's fate. "Unless these things, as I have above proposed," says he, "be once settled, in my fear, which God avert, we instantly ruin; or at least become the servants of one or another single person, the secret author and fomentor of these disturbances." Almost immediately afterwards he addressed a letter to Monk, which was first published by Toland, entitled *The Present Means and Brief Delineation of a Free Commonwealth*; urging him to adopt such measures as seemed best calculated to prevent the restoration of "kingship," and put an end to civil commotion. And, after an interval of a few months, this was followed by another tract, entitled *A Ready and Easy Way to establish a Free Commonwealth*, in which he employs all his eloquence in demonstrating the preference of a republican to a monarchical government, and in exposing the evils which would infallibly result from a restoration. He was accustomed to say, that "the mere trappings of a monarchy could support a commonwealth;" yet, in this work, as well as in his *Brief Delineation*, he betrays an ap-

prehension of an unqualified appeal to the people. The realization of a pure republic he felt to be impossible; and he therefore proposed such a modification of that form of government as would, in his estimation, be a sort of mean between the two extremes of monarchy on the one hand, and a pure democracy on the other.² His last effort in behalf of the republican cause was a short but very forcible commentary, entitled *Brief Notes*, on a loyal sermon preached by Dr Matthew Griffith, one of the late king's chaplains; and with this, to which L'Estrange wrote a sharp reply entitled *No Blind Guides*, terminated the political controversies of the author of *Paradise Lost*.

All his hopes were now blasted. Monk having consummated his perfidy, Charles was advancing to take possession of the throne; and the Latin secretary had acted too distinguished a part in opposition to him and his family, not to be endangered by the event. He was therefore hurried from his house in Petty France, and concealed in that of a friend in Bartholomew Close, where he remained till the passing of the act of oblivion, in the exceptions of which his name was happily not included. To whom, on this emergency, he was indebted for his preservation, has frequently been inquired, and variously explained, but never fully ascertained. The most probable conjecture is, that he was saved by the intercession of his friends Andrew Marvell, Sir Thomas Clarges, and Secretary Morrice, powerfully supported by Sir William Davenant, whom, in 1651, Milton had rescued from similar peril.³ Whilst he remained in concealment, the House of Commons, by a formal vote, condemned his two great political works, the *Iconoclastes*, and the *Defence of the People of England*, to be burned by the hands of the common hangman; the only honour which that servile and degraded body could confer upon them. On the passing of the act of oblivion, 29th August 1660, Milton came forth from his hiding-place, where he had remained nearly four months; but, though his life had been spared, he was still persecuted by his enemies. Towards the close of the same year he was in custody of the serjeant-at-arms, having probably been seized in consequence of a warrant for his apprehension issued by the House of Commons on the 16th of June; but, on the 15th of December, the house ordered him to be forthwith released on paying his fees. Milton, however, appears to have objected to the condition of his discharge; for there is an entry in the journals, dated the 17th, to the effect, that "a complaint being made that the serjeant-at-arms had demanded excessive fees for the imprisonment of Mr Milton, it be referred to the committee of privileges to examine this business, and to determine what is fit to be given to the serjeant for his fees in this case."

On his return to society, Milton took a house in Holborn, near Red Lion Square; but this he occupied only for a short term, as, in 1662, we find him residing in Jewin Street, from which he afterwards removed to a small house in the Artillery-walk, adjoining Bunhill Fields, where he

¹ "To the politician," says Dr Symmons, "who contemplates in this country the advantages of a church establishment, and sees it in union with the most perfect toleration, or to the philosopher who discovers in the weakness of human nature the necessity of present motives to awaken exertion and to stimulate attention, the plan recommended by our author would appear to be visionary or pernicious; and we should not hesitate to condemn it, if its practicability and inoffensive consequence were not incontrovertibly established by the testimony of America. From Hudson's Bay, with the small interruption of Canada, to the Mississippi, this immense continent beholds the religion of Jesus, unconnected with the patronage of government, subsisting in independent yet friendly communities, breathing that universal charity which constitutes its vital spirit, and offering, with its distinct yet blending tones, one grand combination of harmony to the ear of its heavenly Father." (*Life of Milton*, p. 475.)

² This production was made the subject of a sportive and a serious reply. The former, a ludicrous pamphlet, affecting to issue from Harrington's republican club, was called *The Censure of the Rota upon Mr Milton's Book*; and the latter was styled *The Dignity of Kingship asserted*, in answer to Mr Milton's *Ready and Easy Way*.

³ "The principal instrument," says Bishop Newton, "in obtaining Milton's pardon, was Sir William Davenant, out of gratitude for Milton having procured his release when he was taken prisoner. It was life for life. Davenant had been saved by Milton's interest, and in return Milton was saved by Davenant's intercession." For the existence of Davenant's obligation to Milton, we have the testimony of Wood (*Athenæ Oxon.* ii. 412); and for the subsequent part of the story, the evidence may be distinctly traced from Richardson to Pope, and from Pope to Betterton, the immediate client and intimate of Davenant. (Symmons's *Life of Milton*, pp. 489, 490.)

Milton. continued during the remainder of his life. Whilst in Jewin Street he married his third wife, Elizabeth Minshull, daughter of a gentleman of Cheshire. This step was rendered necessary by the undutiful conduct of his two daughters, upon whose attentions he was solely dependent for the management of his domestic concerns. His nuncupative will, which was discovered in the prerogative registry, and published by Warton, affords a glimpse into the interior of his house, and shows him to have been amiable and injured in that private scene, in which alone he has generally been considered as liable to censure, or, at least, not entitled to affection. In this will, and the papers connected with it, we find the venerable father complaining of his "unkind children," for neglecting him because he was blind; and he was even compelled, by their injurious conduct, to appeal against them to his servants. They sold his books; combined with the maid-servant, whom they advised to cheat their father in her marketings; and otherwise acted a most unnatural part. A wife was therefore necessary to rescue him from such undutiful, not to say dangerous, hands; and in the lady whom his friendly physician, Dr Paget, selected for him, he appears to have obtained such a helpmate as his circumstances required. About the time of his marriage he published a short treatise on the *Accidence of Grammar*; and, in the same year, he printed another manuscript of Raleigh's entitled *Aphorisms of State*.

Soon after his establishment in Jewin Street, Ellwood the Quaker was introduced to his acquaintance by Dr Paget. For some years, his daughters, whom he had taught to read Hebrew, Greek, Latin, Italian, Spanish, and French, as well as their own tongue, were in the habit of reading to him such works as he desired; but when this became an irksome employment, and they complained, he released them from the task, and trusted to the kind offices of several friends, whose solicitude to minister to his comfort and enjoyment he gratefully acknowledges in some of his familiar epistles. The kindness of Dr Paget provided him with a more certain and steady resource. Ellwood, in the hope of advancing himself in classical knowledge, solicited an introduction to Milton in the character of a reader; and in this great man, conciliated by the ingenuousness of his manners and the goodness of his heart, the worthy Quaker soon found a friend as well as an instructor. To be near his illustrious friend, Ellwood took lodgings in the vicinity of Jewin Street, and every afternoon, that of Sunday excepted, read to him such Roman authors as he was desirous of hearing. From this accidental intercourse with the author of the *Paradise Lost*, Ellwood is raised into an object of particular interest; and, in the history of his life which he left behind him, he not only speaks with the most affectionate regard of Milton, from whom, he says, he uniformly experienced the kindness of a friend and the instructions of a master,¹ but relates many interesting particulars respecting the literary occupations of his patron, and also gives us an insight into the unassuming and condescending character of the great poet. The following passage in his narrative fixes the date of the completion of the *Paradise Lost*, and also states the origin of the *Paradise Regained*.

"Some time before I went to Alesbury prison,² in 1665,

I was desired by my guardian master, Milton, to take a house for him in the neighbourhood where I dwelt, that he might get out of the city, for the safety of himself and family, the pestilence then growing hot in London. I took a pretty box for him in Giles Chalfont (in Buckinghamshire), a mile from me, of which I gave him notice; and intended to have waited on him, and seen him well settled in it, but was prevented by that imprisonment. But now being released, and returned home, I soon made a visit to him, to welcome him into the country. After some common discourses had passed between us, he called for a manuscript of his; which, being brought, he delivered to me, bidding me take it home with me, and read it at my leisure; and when I had so done, to return it to him with my judgment thereupon.

"When I came home, and had set myself to read it, I found it was that excellent poem *Paradise Lost*. After I had, with the best attention, read it through, I made him another visit, and returned him his book, with due acknowledgment of the favour he had done me, in communicating it to me. He asked me how I liked it, and what I thought of it; which I modestly but freely told him: And after some further discourse about it, I pleasantly said to him, 'Thou hast said much here about *Paradise Lost*, but what hast thou to say of *Paradise Found*?' He made me no answer, sate some time in a muse, then broke off that discourse, and fell upon another subject.

"After the sickness was over, and the city well cleansed and become safely habitable again, he returned thither. And when afterwards I went to wait on him there, which I seldom failed of doing whenever my occasions drew me to London, he showed me his second poem, called *Paradise Regained*, and in a pleasant tone said to me, 'This is owing to you; for you put it into my head, by the question you put to me at Chalfont; which before I had not thought of.'³

It thus appears that, by the middle of the year 1666, Milton had completed his two sacred poems, having occupied in all several years in the composition of *Paradise Lost*, but not more than ten months in that of *Paradise Regained*. The latter, indeed, seems to have been begun and brought to a conclusion during his residence at Chalfont, which probably extended from June or July 1665 to March or April 1666. But it was not until the lapse of a year after their completion that he committed either of these poems to the press. His contract with Samuel Simmons the bookseller, for the copyright of *Paradise Lost*, is dated the 27th of April 1667, and in the course of that year was given to the world the first edition of this mighty effort of intellectual power. "It is a great wonder," says Toland, "this piece should ever be brought to perfection, considering the many interruptions that obstructed it. His youth was spent in study, travelling, and religious controversy; his manhood was employed in affairs of state, or those of his family; and in his latter years, to speak nothing of a decaying fancy, nor of his personal troubles, he was, by reason of his blindness, obliged to write, by whatsoever hand came next, ten, or twenty, or thirty verses at a time, and consequently must trust the judgment of others, at least for the pointing and orthography."⁴ But when this immortal epic poem had, in

¹ Milton had a strong dislike of the English mode of pronouncing Latin. In his letter to Hartlib, he had declared that "to read Latin with an English mouth is as ill a hearing as Law French." He therefore required that Ellwood should learn and practise the Italian pronunciation, which, he said, was necessary in conversing with foreigners. Ellwood complied with this injunction, and finally succeeded, though not without considerable difficulty, in accommodating his pronunciation to the taste of his master. When, in reading the classics, however, his tones betrayed his ignorance of what he read, Milton would, on such occasions, stop him, and explain what seemed not to be understood; thus repaying the trouble of reading with the benefit of instruction. Their intercourse, however, experienced several interruptions.

² He had been seized in a Quaker meeting by a party of soldiers, and, along with his associates, detained for a considerable time in a succession of prisons.

³ Ellwood's Life, pp. 134, 135.

⁴ Toland's Life of Milton, p. 117.

Milton. these painful and affecting circumstances, been completely prepared for the press, its birth was on the point of being intercepted by the ignorance or malice of the licenser, who had been restored with the monarchy, and whose quick nostril detected the scent of treason in the well-known simile of the sun in the first book.

As when the sun new risen
Looks through the horizontal misty air
Shorn of his beams, or from behind the moon,
In dim eclipse, disastrous twilight sheds
On half the nations, and with fear of change
Perplexes monarchs.

Tomkyns, however, was, it seems, appeased, and the *Paradise Lost* saw the light unmutated by malignity or caprice, being born to an immortality of fame.

Much surprise and concern have been expressed at the small pecuniary benefit which the author derived from this proud display of his genius, and at the slowness with which the work laboriously won its way to public estimation. To us, who are accustomed to consider the *Paradise Lost* without any reference to its author or the age in which it appeared, it must certainly seem deplorable that the copyright of such a composition should be sold for the sum of five pounds, and a contingent payment, on the sale of two thousand six hundred copies, of two other equal sums, or fifteen pounds in all. But if we consider the circumstances of the times, and call to mind the prominent part which Milton had taken in defence of the regicides and republicans, we should rather be surprised at the adventurous liberality of the bookseller who would give even this small sum for the production of a man living under the heaviest frown of the restored dynasty, and who was only remembered as the associate and apologist of the men who had overthrown the monarchy. Nor have the reflections which have been made upon the slow apprehensions of the men of that age any better foundation than the strictures which have been passed upon the parsimony of the bookseller. At a time when learning and the love of reading were far from being so widely diffused as at present, the sale of the poem was, all things considered, large and rapid. At the end of two years, thirteen hundred copies had been disposed of; in five years a second edition was issued; after another interval of four years, a third was called for; and before the end of twenty years, it had passed through six editions;¹ "a circumstance," says Dr Symmons, "which abundantly proves that it was not destitute of popularity before it obtained its full and final dominion over the public taste from the patronage of Somers, and still more from the criticism of Addison." In the second edition, which was published in 1674, the author divided the seventh and the tenth book each into two, and thus changed the original distribution of his work from ten to twelve books.

Milton himself informs us that, after much deliberation, "long chusing and beginning late," he fixed upon *Paradise Lost* as the subject of his epic poem; a design so comprehensive that, as Johnson observes, it could be justified only by success. At a very early period of life he appears to have had in contemplation some production in the very highest region of poetry. The idea accompanied him to Italy, where, from the example of Tasso, and the conversation of Tasso's friend the Marquis of Villa, it took the form of a determinate purpose, and seems to have become immoveably fastened in his mind. But although he had made a covenant with his own mind to produce something which men should not willingly let die, yet a long period appears to have elapsed before his choice of a subject was finally determined; and there has been much curious inquiry, and anxious speculation, as to the circumstances by which, after long hesitation, it was at length fixed on *Paradise Lost*. It has been sought to detect the first spark which kindled this magnificent idea in the mind of the poet; and the sublime has been rendered ridiculous by the conceit of an overstrained ingenuity. Voltaire, on his visit to England in 1727, suggested that the original hint of *Paradise Lost* had been supplied by an Italian comedy called *Adamo*, written by Andreini, a strolling player, and stuffed with bombast, conceit, and allegory. This suggestion, however, attracted little notice at the time when it was offered. It has since been rejected with contemptuous disdain by Johnson; and we cannot think, with Dr Symmons, that it has derived any new importance from its adoption by Hayley and Warton.² The conception appears to have developed itself gradually. At first it appeared in a seminal state, pregnant with latent possibilities of excellence; by and by it assumed a more distinct form, striking out roots full of life, and indicative of vigorous vegetation; anon it expanded in growth, and seemed about to take the shape of one of those wild and irregular dramas, anciently called *Mysteries*; and at last, it towered in all its grandeur and magnificence, the mightiest production of creative genius that the human mind has ever elaborated. It is curious to reflect on the steadiness of its growth under a complication of adverse circumstances; it is deeply interesting to behold it, like a Norwegian pine, ascending to a majestic elevation beneath a dreary and inclement sky, deriving its nurture and its strength from the very rocks into the crevices of which it has struck its roots, and braving at the same moment the tempest that rages above, and the wild commotion of the elements below.

The only poem of modern times which can be compared with the *Paradise Lost* is the *Divina Commedia*. The subject of Milton in some points resembles that of Dante, but he has treated it in a very different manner. "The poetry of Milton," says Mr Macaulay, "differs from that

¹ Milton lived to obtain the whole fifteen pounds, for which he had conditionally stipulated, on the 21st of December 1680; and his widow sold the absolute copyright, which he had bequeathed to her, for the sum of eight pounds. Twenty-three pounds was therefore the entire sum which Milton and his family received for the copyright of the *Paradise Lost*. It is curious enough that the instrument by which Milton conveyed this copyright to his publisher was not long ago purchased by Samuel Rogers for the sum of seventy-five or eighty pounds, thus producing to its possessor nearly four times as much as the poem did to its great author. Such is fortune and such is fame.

² The *Adamo* opens with a chorus of angels, and one cherub speaks for the rest in the following strains:

A la lira del ciel iri sia l'arco,
Corde le sfere sien, note le stelle,
Sien le pause e i sospir l'aure novelle,
E'l tempo i tempi a misurar non parco.

This, rendered into prose, reads thus: "Let the rainbow be the fiddlestick of the fiddle of heaven; let the spheres be the strings, and the stars the notes; let the winds mark the cadences; and let time carefully beat the measure." "But," says Voltaire, "Milton pierced through the absurdity of the performance to the hidden majesty of the subject, which being altogether unfit for the stage, yet (for the genius of Milton, and his only) might be the foundation of an epic poem;" and he straightway concludes that, from this "ridiculous trifle," Milton actually "took the first hint of the noblest work which human imagination has ever attempted, and which he executed more than twenty years after." We question much whether the "absurdity" of the player's "performance" be not greatly outdone by that of the critic; and whether, in the competition of nonsense and extravagance, Andreini has not been eclipsed by Voltaire.

Milton. of Dante, as the hieroglyphics of Egypt differ from the picture-writing of Mexico. The images which Dante employs speak for themselves; they stand simply for what they are. Those of Milton have a signification which is often discernible only to the initiated. Their value depends less on what they directly represent than on what they remotely suggest." Whatever Dante undertakes to describe, he never shrinks from describing. His details are exact, and his similes are the illustrations of a traveler. In his descriptions he specifies shape, colour, sound, smell, and taste; he counts numbers, and he measures size. And, with respect to his similes, they are introduced, not for the sake of any beauty in the objects from which they are drawn, not for the sake of any ornament which they may impart to the poem, but simply to make the meaning of the writer as clear to the reader as to himself. They are merely picture-writing translated into words. But how different from these kuriological details are the dim intimations of Milton. He has never thought of taking the dimensions of Satan, but contents himself with giving us a vague idea of vast bulk. The fiend lies stretched out, huge in length, floating many a rood, equal in size to the earth-born enemies of Jove, or to the fabulous kraken which the mariner mistakes for an island. When he turns to do battle with the angels, he towers like Teneriffe or Mount Atlas; and in height he reaches the sky. Compare with this Dante's description of the gigantic spectre of Nimrod, with a face as large and as broad as the dome of St Peter's at Rome, his other limbs in proportion, and his stature such that three tall Germans would in vain have attempted to reach his hair. Again, the lazar-house in the eleventh book of *Paradise Lost* presents the same contrast with the last ward of Malbolge in Dante. Milton avoids loathsome details, and takes refuge in indistinct but solemn and appalling imagery; Despair is hurrying from couch to couch in horrible mockery of the wretches on whom he bestows his unbidden attendance; and Death is brandishing his dart over them, but, notwithstanding their supplications, delaying to strike. Dante, on the other hand, is as physically precise as if he had written his description in a pest-house, whilst his ears were stunned with the moans of the dying, and his nostrils offended with the stench of the dead. Each in his own department is incomparable; and each has, wisely or fortunately, chosen a subject adapted to exhibit his peculiar genius to the greatest advantage. The *Divina Commedia* is a personal narrative; Dante is himself the supposed witness of all that he relates.¹ The *Paradise Lost* is a revelation of things beheld in vision "beyond the flaming bounds of space and time," where even "angels tremble while they gaze," and where imagination may tire itself "without the censure of extravagance."

Of all the poets who have introduced into their works the agency of supernatural beings, Milton is the most successful. In this respect Dante is decidedly inferior to him. Milton, it is true, has been censured for the ambitious attempt to give sensible action to the negative idea of spirit; or, in other words, for ascribing to spirits functions of which, according to our conceptions of spiritual beings, they are incapable. But is this censure well founded, or in accordance with the true principles of poetry? We think not. Spirit is something of which we have no distinct idea. We infer its existence, but we can define it only by negatives, and reason about it only by symbols. We have the name, but we have no image of the thing; and the business of poetry is with images or pictures, not with abstractions. Logicians may reason as they please; but the great mass of mankind can never feel an interest

Milton. in their transcendental speculations. It is through the sensible alone that their minds can be raised to the conception of the invisible and immaterial. The strong tendency of the multitude in all ages and nations to idolatry cannot be explained upon any other principle. The Persians thought it impious to exhibit the Creator under a human form; yet even they transferred to the Sun the worship which, in speculation, they considered as due only to the Supreme Intelligence. This is an inevitable consequence of the condition of humanity, when it is unenlightened by revelation. Hence it may be inferred that a poet who should affect that metaphysical accuracy for the want of which Milton is censured, would scarcely escape a disgraceful failure. His great art, indeed, consists in the very indistinctness with which he has been reproached. On the one hand, it was absolutely necessary for him to clothe his spirits with material forms; and, on the other, he had to avoid such obvious incongruities and contrarieties as neutralize even the most exquisite colouring of fancy, and destroy that illusion, or modified kind of belief, which it is the object of poetry to produce. How was this to be accomplished? It is easy to say with Johnson, that "he should have secured the consistency of his system by keeping immateriality out of sight, and seducing the reader to drop it from his thoughts." Such "seduction" was altogether impossible. The contrary opinion had taken too full possession of the minds of men to be dislodged by the art of the poet; and the attempt to do so would infallibly have annihilated that quasi-belief which poetry requires, and which it misses entirely its object if it fails to produce. Milton, therefore, took his stand between the material and immaterial system, on the confines of the sensible and the spiritual, leaving the whole ambiguous and undefined. By so doing, he has no doubt exposed himself to the charge of inconsistency; but though philosophically in the wrong, we cannot help thinking that he was poetically in the right.² Mystery is the appropriate and indispensable garment of that muse which adventures to sing of the beings and the things which belong to another world.

The spirits of Milton are as unlike those of Dante as the genius of the one poet differs from that of the other. His fiends, too, are wonderful creations. They are neither metaphysical abstractions on the one hand, nor wicked men or ugly beasts on the other. They have enough in common with humanity to be conceivable to human beings; and their characters, like their forms, are marked by a certain dim resemblance to those of men, but expanded to gigantic dimensions, and veiled in mysterious obscurity. Perhaps the gods and demons of Æschylus may best bear a comparison with the angels and devils of Milton; and in the Prometheus of the former may be discovered a considerable resemblance to the Satan of the latter. But such comparison, if pursued, will show the superior, indeed the all-transcending, power of the English poet. Prometheus, for instance, is not sufficiently superhuman. He is too much depressed and agitated; too sensible of pain, too intolerant of misery. His resolution is not sustained by inherent energy, but seems to depend on the knowledge he possesses, that he holds the fate of his torturer in his hands, and that the hour of his deliverance will surely come. "But," in the eloquent language of Mr Macaulay, "Satan is a creature of another sphere. The might of his intellectual nature is victorious over the extremity of pain. Amidst agonies which cannot be conceived without horror, he deliberates, resolves, and even exults. Against the sword of Michael, against the thunder of Jehovah, against the flaming lake and the marl burning with solid fire, against the

¹ Edinburgh Review, vol. xlii. pp. 316, 317.

² *Ibid.* p. 320.

Milton. prospect of an eternity of uninterrupted misery, his spirit bears up unbroken, resting on its own innate energies, requiring no support from any thing external, nor even from hope itself." In regard to the personifications of Sin and Death, with the actions attributed to them, we must dissent in opinion from both Addison and Johnson. When Milton formed these personages, and blended them with the agents of his poem, he appears to have availed himself of an indisputable prerogative of his art; and if any authority were wanted to support this particular exercise of the privilege, it might be found in the sacred Scriptures. In these Sin is more than once distinctly personified; and Death is not only described as the last enemy whom the Son of God is to vanquish, but, in a sublime passage of the Apocalypse, he is invested with a specific and formidable agency, mounted on a pale horse, with all hell following in his train.¹

But, without prosecuting contrasts, or entering further into details, we may observe generally, that *Paradise Lost* may be considered, first, with reference to the plan and arrangement of the poem; secondly, in regard to the subject, with its difficulties and advantages; thirdly, as respects the poet's object, the ἐνθυμιον ἐν μυθῳ, or the spirit in the letter of the fable; and, lastly, as to its characteristic excellencies. The plan is remarkable for its exquisite simplicity and its unity. In the *Iliad* many of the books might change places without any detriment to the story. But it is not so in *Paradise Lost*. That poem alone really has a beginning, a middle, and an end; it possesses a totality by which it is distinguished from the *ab ovo* birth and parentage or straight line of history. As to the subject, again, the superiority of *Paradise Lost* is obvious in this respect, that, unlike the *Iliad*, which is a Greek poem, and languid to all but Greeks, the interest transcends the limits of a nation or race; its main excellence is attributable to Christianity, yet the interest is in fact wider than Christendom, comprehending also the Jewish and Mahomedan worlds. In Homer, the supposed importance of the subject is an after-thought of the critics; in Milton, its real importance is inseparably blended with the present condition and future destinies of man. Nor is the object of the poet unsuited to the grandeur of his design; it is

That to the height of this great argument
He may assert eternal Providence,
And justify the ways of God to man.

It is to be observed, however, that his views in this respect take their colour from the great controversy of his age, namely, the origin of evil. He asserts the will, but declares for its enslavement out of an act of the will itself. Lastly, as to the execution, the language and versification are peculiar, in being more necessarily correspondent to each other than in any other poem. The connection of the sentences, and the position of the words, are exquisitely artificial; but the collocation is rather according to universal

logic, or the general laws of human thoughts, emotions, and passions, than according to the more confined logic of grammar.² Milton attempted to make the English language obey this logic as perfectly as the Latin or the Greek; to impart to it the susceptibility of diversified collocation which distinguishes the one, with something of that wonderful flexibility and power of adaptation which forms the prominent characteristic of the other; and, notwithstanding occasional harshness of construction, he has been astonishingly successful. In fine, sublimity constitutes the pre-eminent attribute of the *Paradise Lost*.³ There is a greatness arising from images of effort and daring, and also from those of moral endurances; in Milton both these kinds are united. From the causes already explained, his fallen angels are invested with a dramatic reality, which is the more astonishing, considering the difficulty of giving to spiritual natures distinctness and individuality.⁴

In 1670 Milton published his *History of England*, and in 1671 he gave to the world the *Paradise Regained* and the *Samson Agonistes*, poems of very unequal merit. *Paradise Regained* was probably considered by the author as the theological completion of his design; and he is said to have regarded it with a strong preference. But it possessed no charms for the multitude, notwithstanding the weight of sentiment and knowledge which it everywhere displays; and it seems to have immediately fallen into that state of neglect from which, in spite of all the efforts of Jorton, Warburton, and Dunster, it has never since had the good fortune to emerge. Yet it is by no means unworthy of the author. It is embellished with several exquisite passages, and, in some of its finer parts, it shows the undiminished power of the author of *Paradise Lost*. The *Samson Agonistes* is a drama composed upon the ancient model, but, like the *Comus*, it is in reality a lyric poem in the form of a play. Its delineation of character, though not various, is discriminate and just; its sentiments are full of dignity; its diction is severe, exquisite, and sublime; and the whole is overshadowed by a gloomy majesty, which at once subdues and elevates the imagination.

Milton did not disdain to perform the humblest services to literature. Having already condescended to publish a book of Latin Accidence for the use of children, he now, in 1672, supplied the young but more advanced student with a scheme of logic digested on the plan of Ramus, and entitled *Artis Logicæ plenior Institutio ad Petri Rami Methodum concinnata*. In 1673, he published a short treatise, entitled *Of true Religion, Heresy, Schism, Toleration, and what best Means may be used against the Growth of Popery*. Milton was as little tolerant of papists as of prelates, and for the same reasons; he conceived (whether rightly or not is another question) that both were equally inimical to the existence of perfect civil and religious liberty. But it must not be supposed that he gave any countenance to persecution. On the contrary, the object of this treatise was to show, first, that no true Protestant

¹ Edinburgh Review, vol. xlii. pp. 321, 322. Symmons's Life of Milton, pp. 530, 531.

² Coleridge's Literary Remains, vol. i. p. 171, et seq.

³ Channing's Remarks on the Character and Writings of John Milton have been extolled by many persons, who impeach their own judgment by such commendation. They are merely pulpit criticisms, constructed on the false principle of making out a case for Milton, as if his fame required the help of such exaggeration. They are elaborate and magniloquent, but neither new nor discriminating; and, to speak freely, the whole seems to be a laboured and somewhat tumid paraphrase of Lord Bacon's well-known definition of poetry, a tissue of ambitious commonplace.

⁴ The following well-known lines of Dryden show how just an estimate he had formed both of the comparative and the absolute merits of Milton:

Three poets in three distant ages born,
Greece, Italy, and England did adorn:
The first in loftiness of thought surpassed;
The next in majesty; in both the last;
The force of nature could no further go:
To make a third, she joined the former two.

Milton. can persecute another on account of his religious opinions, without renouncing the main principles on which true religion is founded; and, secondly, to make it appear that popery, by placing human tradition above the Scriptures, and by inculcating implicit obedience to the pope as a temporal prince, is inimical to religion and to social order. The principle of toleration which he lays down is agreement in the sufficiency of the Scriptures; and this he denies to the papists, because they appeal to another authority. In the same year, he published a second edition of his youthful poems, with his *Tractate on Education*, in one volume, including some pieces not contained in the edition of 1645. In 1674, the last year of his honourable and laborious life, he published his familiar letters, and some university exercises; the former under the title of *Epistolarum Familiarium Liber unus*, and the latter under that of *Prolusiones quædam Oratoriæ in Collegio Christi habitæ*. He is also said, although on doubtful authority, to have translated into English the declaration of the Poles on elevating John Sobieski to the throne; and, with more probability, to have written, in the same year, a *Brief History of Muscovy*, which was published about eight years after his decease.

His health now declined fast, and the gout, which had for many years afflicted him, attacked him with a severity which prognosticated a fatal termination; yet such was the buoyancy of his spirits, that, even in the paroxysms of the disease, he would, according to Aubrey, "be very cheerful and sing." On Sunday the 8th of November 1674, he expired without pain, and with so little appearance of death, that his departure was unperceived by the persons who waited in his bed-chamber. He closed a life ennobled by the constant exercise of high and rare endowments, in the sixty-sixth year of his age; and was buried in the chancel of St Giles, Cripplegate, all his learned and great friends in London accompanying his body, "not without a friendly concourse of the vulgar."¹

In the July preceding his decease, Milton had requested the attendance of his brother Christopher, and, in his presence, had made a disposition of his property by a formal declaration of his will. By this nuncupative testament, he bequeathed the whole of his property to his widow, assigning nothing to his daughters but their mother's portion, which had not yet been paid, and the sums which he had expended upon their education. But after a full hearing of the cause, on a suit instituted against it by the daughters, the will was set aside, on the ground of certain informalities, by a decree of the judge of the Prerogative Court. The property which was thus ineffectually be-

queathed to the widow is said to have amounted to about fifteen hundred pounds, exclusively of goods. The publication of this will by Mr Warton has completely refuted the charge of unkindness to his children, which has often been alleged against Milton, and proves, as we have already shown, that he had but too good reason for his conduct in this matter.

Milton left three daughters, all by his first wife. Anne, the eldest, married a master builder, and died in her first confinement; Mary, the second, died in a single state; and Deborah, the youngest, married Abraham Clarke, a weaver in Spitalfields, by whom she had seven sons and three daughters. The distress into which she fell in consequence of this imprudent marriage experienced some late and partial relief from the liberality of Addison, and the less splendid munificence of Queen Caroline. Of her ten children two only left offspring; Caleb, who, marrying in the East Indies, had two sons, whose history cannot now be traced; and Elizabeth, who married Thomas Foster, a weaver, by whom she had three sons and four daughters, who all died young and without issue. In old age and in penury, Mrs Foster was discovered in a small chandler's shop, and brought into public notice by Dr Birch and Dr Newton. Attention being thus awakened to the granddaughter of Milton, *Comus* was performed for her benefit in 1750; and Johnson, associated as he then was in the labours of the infamous Lauder, did not hesitate to supply the occasional prologue.² The profits of the night were only L.130; yet this was the greatest benefaction that the *Paradise Lost* ever procured the author's descendants. Mrs Foster died on the 9th of May 1754, and with her expired the last descendant of the immortal poet.

In his youth Milton was so remarkable for the fineness of his complexion, and the beauty of his features, that at Cambridge he was called "the lady of Christ's College." His eyes were dark grey, but full of animation; and his hair, which was light brown, he wore parted at the top, and clustering, as he describes that of Adam, upon his shoulders. His person was of the middle size, and well proportioned; not fat nor corpulent, but muscular and compact. In early life he was fond of manly sports, and excelled in the exercise of the sword. When blindness and the gout confined him in a great measure to his house, he contrived a swing for the purpose of exercise, as the essential preservative of health, and to this he regularly allotted one hour a day. His habits were those of a severe student, and a rigid economist of time. His temperance, varied by intervals of abstinence, we have

¹ Toland's *Life of Milton*, p. 137.

² For information as to Johnson's undoubted connection with Lauder, the reader is referred to Dr Symmons's *Life of Milton*, Appendix, p. 618, et seq. In fact, Lauder's essay, entitled *Milton's Use and Imitation of the Moderns*, in which he asserted that the author of the *Paradise Lost* had been guilty of numerous plagiarisms from some modern Latin poets of very inferior note, and produced from their works pretended extracts in support of his alleged discovery, is ornamented with a preface and a postscript by Johnson, who thus made himself an accomplice in the malignity, even if we admit his ignorance of the frauds committed by Lauder. But public detection and exposure awaited the forger. The whole mystery of iniquity was revealed to the world by Dr Douglas, afterwards bishop of Salisbury, who, in a pamphlet entitled *Milton vindicated from the charge of Plagiarism brought against him by Mr Lauder*, laid bare a system of imposture unparalleled in the history of literature, and showed with what impudence the passages cited from Masenius, Staporstius, Taubmannus, and other obscure writers, had been adapted to the forger's design by the interpolation of lines either immediately fabricated for the purpose, or transcribed without alteration from Hogg's Latin translation of the *Paradise Lost*. Lauder, when convicted, addressed to Dr Douglas a letter of penitence and confession, which was written for him by Johnson, who no doubt felt it necessary to disavow his association with falsehood, but which, with characteristic duplicity, Lauder represented as his own composition. The criminality of the latter, however, required not this plea of guilty to insure condemnation. After a vain attempt to conciliate the high royalist party, by a miserable attempt to vindicate Charles I. from the charge of plagiarism, and to prove that Milton had interpolated the *Eikon Basiliké* with Pamela's prayer from the *Arcadia* of Sidney, the unhappy wretch was compelled to fly from popular resentment to the West Indies, where he sunk into the grave amidst penury and contempt. Johnson, more fortunate than his coadjutor, survived the disgrace of this infamous alliance, to enjoy the opportunity of attempting, with deeper malignity, though not with any better success, to inflict a mortal wound on the invulnerable reputation of Milton.

Multi

Committunt eadem diverso crimina fato;

Ille crucem sceleris pretium tulit, hic diadema.

JUVENAL. *Sat.* xiii. l. 103.

For abundant proofs of Johnson's injustice, see *Animadversions on his Life of Milton*, appended to Ivimey's biography of the poet, p. 349, et seq.

Milton. already noticed. In his youth he studied late, and prolonged his vigils far into the night; but he afterwards corrected this practice, retired to bed at the early hour of nine, and usually rose with the sun. The opening of his day was uniformly consecrated to religion. When he rose he heard a chapter of the Hebrew Bible read, and then occupied himself till twelve in private meditation, in listening whilst some author was read to him, or in dictating as some friendly hand supplied him with its pen. At noon commenced his hour of exercise, which was succeeded by his early and frugal dinner; after which he either played on the organ, or sung, or heard some one else sing. From music, of which he was passionately fond, he returned with fresh vigour to study or composition. At six he received the visits of his friends; at eight he supped; and at nine, having smoked a pipe and drank a glass of water, he retired to his repose. Such was the scheme of his daily life.

His personal character corresponded with his high intellectual endowments. His manners were affable and graceful; his conversation was cheerful, instructive, and engaging. In his whole deportment, however, there was visible a certain elevation of mind, something of a conscious superiority, which could not altogether escape observation. His temper was grave without any taint of melancholy; he was bold in conception, and persevering in the execution of his purposes. His kindness was ardent, his resentments were keen; but the former was permanent, the latter were transitory; his friendships were lasting, his enmities expired with the immediate occasion. In his domestic relations, his conduct seems to have been unimpeachable; and if he was not fortunate in his family, no part of the blame rested with him. He was disinterested, generous, and forgiving. The malignant slanders of his enemies sometimes betrayed him into unbecoming recriminations; but his conduct to the Powells, who had so wantonly injured him, and other circumstances in his life, establish his superiority to any feeling of a vindictive nature. As to his own purity and sanctity of soul, the earnest and fearless declarations contained in his prose writings make it impossible to doubt. These he made before his most bitter enemies, rendered furious by a common cause, in which all the principles of ancient institutions were involved; yet none attempted to disprove them, scarcely any dared to call them in question. Johnson, in his biographical libel on Milton, a production worthy of the coadjutor of Lauder, has had the baseness to stigmatise him as "morose and malevolent," as "impatient of social subordination, yet oppressive to those within his power," as at once "a rebel, a tyrant, and a sycophant," with much more to the same effect that is equally disgusting and false; but these slanderous imputations have been refuted by irrefragable evidence, and the life of the patriot and poet has been shown to be as pure as his soul was lofty and his genius unrivalled.

In strictness, Milton did not belong to any of the classes into which, in his time, his countrymen were divided. In his character the noblest qualities of every party were combined in harmonious union. "From the parliament and from the court," says an eloquent writer, "from the conventicle and from the Gothic cloister, from the gloomy and sepulchral circles of the Roundheads, and from the Christmas revel of the hospitable cavalier, his nature selected and drew to itself whatever was great and good, while it rejected all the base and pernicious ingredients by which those finer elements were defiled."¹ He lived "as ever in his great taskmaster's eye," keeping his mind con-

tinually fixed on an Almighty Judge and an eternal reward; and hence he acquired that fortitude, tranquillity, inflexible resolution, and contempt of external circumstances, for which the puritans were distinguished. But he was perfectly free from their wild delusions, savage manners, and ludicrous jargon, their contempt of science, and their aversion to innocent pleasure. There was none who had a stronger sense of the value of literature, a finer relish for every elegant amusement, or a more chivalrous delicacy of honour and love. Though his opinions were democratic, his tastes and associations were such as harmonize best with other forms of government. But of these natural predilections or tendencies he was the master, not the slave; he enjoyed the pleasures of fascination without being fascinated; the politician was proof against the splendid illusions which enchanted the imagination of the poet. This will be understood by any one who contrasts the sentiments expressed in his treatises on prelacy, with the exquisite lines on ecclesiastical architecture and music in *Il Penseroso*, which were nearly contemporaneous productions. But the public character of Milton derives its great and peculiar splendour from another source. The glory of the battle which he fought for that species of freedom which is the most valuable, and which was then the least understood, is exclusively his own. Here there is none to divide the palm with him. He looked farther and saw deeper than the men of his time. The objects which he justly conceived to be the most important, escaped the observation of his countrymen. They indeed raised their voices against Ship-money and the Star-chamber, because all felt the pressure of the arbitrary impost, or were liable to oppression by the tyrannical tribunal. But it was reserved for Milton alone to discern the more fearful evils of moral and intellectual slavery, and point out the benefits which would result from the liberty of the press, and the unfettered exercise of private judgment.²

Todd has, with laborious industry, collected a list of the editions of Milton's poetical works, amounting in all to a hundred and four. The *Paradise Lost* has been translated into Greek, Latin, Italian, French, German, Dutch, and Portuguese; and of the other poems several have likewise been translated into various languages. The best Italian translations are those of Rolli and Mariottini. Of the French translations of *Paradise Lost*, there are four in prose and six in verse; but, upon the whole, the preference seems to be due to that of Jacques Delille, the celebrated author of the *Jardins*, which is enriched with an able preface by Michaud, the historian of the Crusades. "D'autres traductions estimables ont paru de nos jours," says Villemain, "mais le monument qui a naturalisé parmi nous la gloire et la génie du poète Anglais c'est la traduction en vers de Jacques Delille. Nulle part Delille n'a montré un plus riche et plus heureux naturel, plus d'originalité, de chaleur, et d'éclat. Les négligences, les incorrections même, abondent, il est vrai, dans cet ouvrage, écrit avec autant de promptitude que de verve. Le caractère antique et simple de l'Homère Anglais disparaît quelquefois sous le luxe du traducteur. Ce n'est pas toujours Milton, mais c'est toujours un poète."³ Of Milton's works, thirty-five in number, thirty-three have been particularly noticed in the course of the preceding article, where they are arranged and described in their true order. The pieces omitted are of very inferior importance, being, 1. Joannis Philippi Responsio ad Apologiam Anonymi cujusdam; and, 2. Litteræ Senatus Anglicanæ which has been incidentally referred to. (A.)

¹ Edinburgh Review, vol. xlii. p. 342.

² Ibid. p. 343.

³ Biog. Univer. art. MILTON.

Milverton
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Minag-
ghinim.

MILVERTON, a town of the county of Somerset, in the hundred of its own name, 152 miles from London, and three from Wellington. It was a borough, but lost its franchise many years ago. It was once a place where woollen cloths, serges, druggets, and other goods, were extensively made, but the trade has greatly fallen off of late years. There is a market on Friday. The population amounted in 1801 to 1667, in 1811 to 1637, in 1821 to 1930, and in 1831 to 2233.

MIMI, **MIMES**, in the ancient comedy, were buffoons or mimics, who entertained the people by taking off certain characters, and using such gestures as suited the persons or subjects they represented. There were upon the Roman stage female performers of this kind, called *mimæ*. The word is derived from *μιμωσμαι*, *I imitate*. Some of the *mimi* acted their parts to the sound of the *tibia*, and were called *mimauli*.

MIMI were also a kind of farces or ludicrous comedies, generally performed by one person. They had no acts, nor any *exordium*.

The *mimi* were introduced upon the Roman stage long after comedy and tragedy had arrived at their full perfection. The actor wore no mask, but smeared his face with soot, was dressed in lamb-skin, wore garlands of ivy, carried a basket of flowers and herbs in honour of Bacchus, and diverted the audience with apish tricks and ridiculous dances. This was the state of the *mimi* soon after their first introduction; but they underwent many alterations, which it would occupy too much room to relate, and which are not of sufficient importance to justify a detailed account.

MIMESIS, in *Rhetoric*, the imitating the voice and gestures of another person.

MIMNERMUS, an ancient poet and musician, flourished about the beginning of the sixth century before our era. He was a native of Smyrna, and contemporary of Solon. Athenæus ascribes to him the invention of pentameter verse. His elegies, of which only a few fragments are preserved, were so much admired in antiquity, that Horace preferred them to those of Callimachus. He composed a poem of this kind, as we learn from Pausanias, upon the battle fought between the people of Smyrna, and the Lydians under Gyges. He was likewise author of a poem in elegiac verse, quoted by Strabo, which he entitled *Nanno*, and in which we may suppose he chiefly celebrated a young and beautiful girl of that name, who, according to Athenæus, was a player on the flute, and of whom he was enamoured in his old age. With respect to love matters, according to Propertius, his verses were more valuable than all the writings of Homer.

MINA, or **MANEH**, a species of money which properly signifies *one part* or *ounce*. It is observed that this word occurs only in the books of Kings, Chronicles, Ezra, and Ezekiel. The prophet (xlv. 12) tells us, that the mina or maneh was valued at sixty shekels, which in gold are equivalent to L.54. 15s. of English money, and in silver to about L.7. Thus for the Hebrew maneh. But the Greek or Attic mina, which is probably that mentioned in the books of the Maccabees and in the New Testament, is valued at a hundred drachmæ, or about L.2. 17s. sterling. There was also a lesser mina, which was valued at seventy-five drachmæ.

MINA, a small town of Arabia, about twenty miles to the south of Mecca, on the way to Mount Arafat. It is situated between two granite mountains, and consists of a single long street, containing several handsome houses.

MINAGNGHINIM, an instrument of music amongst the Hebrews. It was a square table of wood, fitted with a handle; and over this table was stretched an iron chain, or hempen cord, passing through balls of wood or brass, which struck against the table when the instrument was shaken,

and occasioned a clear sound, that might be heard at a great distance.

MINAS GERAES, an important interior province of Brazil, in South America. On the south it is separated from the provinces of Rio and St Paulo by a mountain chain called the Serra Mantiqueira; on the north the rivers Verde and Carynhenha divide it from Bahia and Pernambuco; on the east it is bounded by part of Bahia, Porto Seguro, and Espiritu Santo; and on the west by Goyaz. It is situated between the thirteenth and twenty-second parallels of south latitude, and is above six hundred miles in length by about three hundred and fifty in average breadth. This is the most mountainous province in Brazil. Hills swell up in every direction, forming an elevated table-land, and the country gradually assumes the features of a romantic alpine region. The golden mountains traverse the whole extent of the province, but they do not rise more than 4000 feet above the level of the sea; nor are they characterised by rugged cliffs or gigantic rocky summits, such as the Alps or Cordilleras exhibit. They consist of long series of detached ranges, having agreeable campos on their summits, and are separated from one another by sloping and pastoral, but not very deep valleys. Owing to the elevation of its table-land, the climate of Minas Geraes is temperate when compared with other countries under the torrid zone; and none of the provinces of Brazil abound more with rivers and mountain torrents. Of these, the greater part have their origin in the Serra Mantiqueira, and are received by four general channels. Two of them, the Rio Doce and the Jequitinhonha, flow to the eastward, the former irrigating the comarca of Villa Rica, and the latter that of Serro do Frio. The St Francisco has a northerly course, and waters the comarca of Sabara; whilst the Rio Grande, or Para, takes a westerly direction, after receiving the Rio das Mortes, which gave its former name to the comarca of St Joao del Rey. The soil in general is very fertile, yielding in abundance, and with little trouble, the grains and fruits of Europe; besides the aromatic plants and other vegetable productions characteristic of such regions, such as cotton, tobacco, sugar, maize, mandioc, coffee, indigo, ipecacuana, columbo root, jalap, liquorice, vanilla, various gums, and Jesuits' bark. The grape yields a delicious wine, but the inhabitants of the gold and diamond districts drink a humbler liquor, and neglect their vineyards. The forests in this province have only been partially explored, and they still constitute strongholds of the Indians. The trees of which they consist are consequently little known, but many of them are well adapted for dyeing and tanning. These arts, however, have hitherto made little progress, as the inhabitants are averse to employments of this nature, their attention being chiefly directed to the glittering but often useless treasures found in the bowels of the earth. The adraganth, or dragon's gum, in this district, is of the best quality. The sugar-cane grows in a wild state; the roads are covered with arcades formed by its branches, which reach in many parts to the height of thirty feet. The cattle are allowed to go at large on the open tracts of the country, and left to subsist on whatever they can find. In the summer months, when the grass throughout the wide extent is withered and burnt, they flock to the margins of brooks; but this resource soon fails them, and vast numbers perish from hunger. This province is very rich in mineral productions, and here the principal mines of gold and diamonds are situated. The following metals and minerals are also found: Platina, silver, copper, iron, lead, mercury, antimony, bismuth, fossil-coal, sulphur, emeralds, rubies, topazes, chrysolites, sapphires, agates, aqua-marinas, amethysts, and almost all the precious stones.

Minas Geraes is divided into five comarcas; namely, St Joao del Rey, Sabara, Paracatu, Villa Rica, and Serro do

Minas Geraes.

Minas Geraes. Frio. In drawing up an account of these, we have been chiefly indebted for information regarding them to the works of Mr Mawe, Mr Luccock, and Drs Von Spix and Martius. We shall follow the route of the first-named traveller from the frontier to Villa Rica. At rather more than a league's distance from the river Paraibuna is Rosinha do Negro, a small village, situated, like others in this part of the country which are connected with a large plantation, at the bottom of a deep hollow, and by the side of a small stream. Two leagues farther on is another register, called Mathias Barboza, formed by mud-walls, enclosing a large area, with a gateway at each end, through which the public road passes. This place is the great toll-house of Minas Geraes, and the duties collected, amounting to L.25,000 annually, are every three months remitted to Villa Rica. The road, which lies through extensive tracts of wood, continues to ascend in a direction north-west by north; and there is a very sensible change in the temperature. Amongst the trees are the pine and the common box-tree, the latter attaining a height of more than twelve feet. As the road continues to ascend, the trees get smaller, the heaths and ferns larger and more vigorous, and the air becomes cool and fresh, except between the hours of two and four P. M. Several fazendas succeed one another at intervals as the traveller proceeds on his journey to the capital. That called Mantequeira is situated in a large plain, consisting of rich land, watered by numerous streams, but overrun with weeds and brushwood. Some leagues further inland is Barbazena, which consists of between three and four hundred houses, and where a considerable traffic was at one time carried on with the interior in baize, cotton goods, salt, and iron. Much of the trade, however, is now removed to St John's. Barbazena is pleasantly situated on the southern declivity of a considerable hill, and here the two great roads from the mining country unite; the one to the westward leading to St Joao del Rey, Sabara, and Cujaba; the other in a northerly direction, conducting to Villa Rica, Tijuco, and Minas Novas. In the vicinity of a place called Louza there is a hill covered with micaceous iron ore, and the road for above half a mile is strewn with a rich oxide of iron. At Alto de Virginia and S. Antonio do Ouro Branco are extensive gold washings; but between these places and the capital the route lies over bleak and sterile mountains.

Villa Rica, the capital of Minas Geraes, dates its title as a town no further back than 1711, previously to which period it bore the name of Piro Oreto (black gold), which is still retained by the mountain on the eastern declivity of which it is situated. It occupies two hills, and part of the circumjacent valley or hollow. The principal street runs for nearly two miles in a straight line along the slope of the Morro. Several streets lead from the lower part of the city to that situated on the high ground; and they are all paved, and connected by four stone bridges. The houses are built of stone, two stories high, covered with tiles, and in general white-washed. It is well supplied with water from a number of public fountains distributed through the town. Amongst the public buildings, some of which are not without a claim to splendour, is the governor's palace, which is situated on the highest projection of the hill; and opposite is a group, of which the inhabitants are particularly proud, formed by the town-house, the prison, and the theatre. In one of the

lower parts of the town stands the treasury, attached to which are the mint and the custom-house. There are ten churches, several of which are richly ornamented, and contain paintings and images. Villa Rica enjoys a very considerable trade. Almost every week large convoys set out with the productions of the country, consisting of cotton, hides, marmalade, cheese, precious stones, bars of gold, and other articles. In exchange they bring back salt, wines, calicoes, handkerchiefs, hams, iron-ware, and negroes to be employed in the gold washings and other occupations. Almost all kinds of trades are here carried on; the principal are saddlers, tinmen, and blacksmiths. There are likewise manufactories of gunpowder, hats, and pottery; and they spin and weave wool, worsted, and cotton; but the trade of the goldsmith is prohibited. All the manufactures are purely domestic; and the implements and modes of using them are of the oldest and most unimproved description. The climate of this city is delightful, being equal, it is said, to that of Naples. The range of the thermometer in summer is from 64° to 80°; and in winter it rarely descends below 50° of Fahrenheit. From the great elevation of the city, however, it is subject to sudden alternations of temperature during the course of a single day, and thunder-storms are frequent. Both soil and climate are remarkably favourable to fruits and vegetables, and numerous orchards are situated on the side of the mountain. The system of horticulture, however, is very bad; and, notwithstanding the fertility of the country, the market is but ill supplied with culinary articles. Of the population it is difficult to form an estimate, as the amount is given by different travellers at from eight thousand to twenty thousand; and Mr Luccock states that it is continually fluctuating. According to one traveller, the greater part of the inhabitants consist of blacks and mulattoes; another says there are more whites than blacks; and a third states that there is a considerable proportion of Portuguese.

This is the very centre of the gold country, and a somewhat particular description of this extraordinary spot is necessary. "To contemplate the gold mines of Villa Rica with advantage," says Mr Luccock, "it will be necessary to recollect, that the land is composed of schist, or a sort of slaty clay, resting upon a core of granite, gneiss, or sandstone, sometimes laminated, at other times solid, the gold being scattered in small particles amid the superjacent schist and clay; and that the town is placed at the junction of several streams, whose waters have only one outlet by a narrow bason, cut by their force through the surface down to the more firm component parts. Before this outlet, called the Rio do Carmo, became so deep as it is, a small lake must have existed among the hills, through which all the waters of the upper country passed, bringing with them and depositing in the bottom a variety of heavy matter." By this means the ground was raised, whilst the outlet was deepened, until the water was entirely drained off; thus leaving the bottom dry, in the shape of a level plain, composed of the debris of various kinds, mingled with which was a considerable quantity of gold. This plain is surrounded by mountains containing, it is supposed, much gold, notwithstanding what has been washed down or extracted from them. A stream traverses the plain, and, when flooded by rain, small trenches are formed on its banks, into which the water runs, and,

¹ Dr. Von Spix, however, denominates the superjacent stratum an ironstone flötz, consisting partly of clay coloured by oxide of iron, but principally of lithomarge, generally of a reddish-brown colour. In this mass there is a large quantity of compact brown ironstone; and also detached nodules of quartz, mica slate, and, though rarely, fragments of topazes. The gold in this formation occurs either in very small grains and crystals within the layers of clay and lithomarge, or as a coating on brown ironstone, or imbedded in it in folia. Below this ironstone flötz is a species of mica slate, containing a large proportion of iron; and through the mass there is disseminated a considerable quantity of gold, particularly in the quartz veins by which it is traversed. Gold in abundance is likewise found in other formations.

Minas Ge- depositing the sediment suspended in it, more or less
raes. gold is generally mingled with the mass; and on the occasion of a flood the whole of the inhabitants turn out and pursue the search for the precious metal. On the side of the hill the bottoms of the natural streams are searched, and where these do not exist, excavations are formed, and the courses of streams are turned and made to pass through them. So numerous are the perforations of this kind, that the side of the mountain presents the appearance of a honey-comb. The greatest quantity of gold has been found on the eastern declivity of the Morro of Villa Rica, and here the search for it is conducted more systematically. Sieves and raw ox hides are placed at certain distances in trenches full of water, which is conducted from the summit; the first is intended to stop the coarser sand, and the second is to catch the gold dust in the hair, which stands erect; sometimes woollen cloths are used for this purpose. The gold found here varies in colour according to the nature of the other metals or minerals with which it is mixed. The Morro of Villa Rica extends in a direction east and west along the valley of the Ribeiro do Oiro Preto or do Carmo, to Passagem, a village containing about one hundred and fifty houses, situated about two leagues from the capital. Gold mines or washings are likewise situated in the vicinity of the episcopal city of Mariana (see MARIANA), at the Presidio de St Joao Baptista, on the Rio de San Joze, where it washes the base of the Altos de St Miguel, at the aldea of St Joze de Barra Louga, and at various other places throughout the province. A district in which the beautiful fazenda of Capao is situated, is that where the well-known Brazilian topazes are found. What is called the topaz mine is only an open quarry, consisting of two breaks or slips in the mountain side. These precious stones are found in three different places. The mine which Dr Von Spix examined was a hill immediately behind the fazenda of Lana, which, on one side, for a considerable breadth and to a height of sixty feet, had become so softened by rains, and by water conducted upon it by art, that it had become like a marsh. The soil is thrown up into long heaps with shovels, and washed, by means of water conducted over it, into a narrow channel, with some wooden lattices fixed in it, so that only the more solid parts remain behind, which are then broken with hoes, and with the hands in search of topazes. The quantity found here annually may amount to between fifty and sixty arrobas, but many of them are of an inferior quality. The greater part of these topazes is exported from this place to Rio de Janeiro, and a smaller portion to Bahia. The euklase is also found here, and has attracted the attention of the mineiros since mineralogists have inquired after it. This stone is in general scarce, and is more frequently met with in the mine of Capao than in that of Lana. Five leagues to the westward of Capao is the iron foundry of De Prata, which produces annually about one thousand arrobas of iron. The ore is a rich iron glance, but particularly magnetic iron stone, the very thick beds of which stand out near the foundry. The rock is mica slate. A league and a half to the south-south-east of De Prata are the gold and lead mines of Senhor Romualdo Joze Monteiro do Barros. The gold mine is a cream-coloured clay slate traversed by auriferous veins of quartz, amongst which the metal is disseminated, along with manganese. The mine of Cujabeira, in which the chromate of lead is found, is a low hill of clay, scarcely a league distant from the fazenda. The red lead ore is found in a vein of friable, grayish-white, granular quartz, amongst pretty much integrated, white, scaly lithomarge. The crystals of the chromate of lead are very small, and seldom show well-defined terminal planes. Not far from this estate is the arraial of Matozinho, which contains about one hundred and fifty houses, with several churches; and on the

opposite side of the river Paraopeba is situated Congon- Minas Ge-
has, containing about two hundred houses, and several raes. chapels, one of which, although small in dimensions, vies in the splendour of its ornaments with any ecclesiastical edifice in the country. It has indeed been designated the Loretto of Brazil. In external appearance it is not more than respectable, but the interior decorations and emblazonry, consisting of the precious stones of Brazil, are on the most splendid scale. Eight miles to the north-east of Marianna is the arraial of Antonio Perreira, where gold mines are situated; but we must now quit the land of gold for the land of diamonds, situated in the comarca of Serro do Frio

The comarca of Serro do Frio is divided from that of Villa Rica by the river Doce. Villa do Principe, the capital, is situated about one hundred and ten miles north-north-east of Marianna, close upon the confines of the diamond district. Like the other provincial capitals of Minas, this town has its smelting-house, with the usual appointments, its ouvidor, who holds also the office of mint master, and a *juiz de fora*. It contains a church, five chapels, and about five thousand inhabitants, a considerable portion of whom are shopkeepers, the rest being artisans, farmers, and miners. The country around Villa do Principe is very fine and open, being free from those impenetrable forests which occur so frequently in other parts of the province. The climate is mild and salubrious; the soil is productive, yielding Indian corn, legumes, cotton, and sugar. A few leagues beyond this town the aspect of the country changes, and the district in which Tejuco is situated is sterile and unproductive. This town is irregularly built on the side of a hill, and contains a church, several chapels, and a number of shops stocked with English cottons, baizes, and cloths, with other kinds of manufactured goods. What is termed the diamond ground extends about sixteen leagues from north to south, and about eight from east to west; and several thousand negroes, who are superintended by about two hundred whites, are employed in searching for the precious mineral. The largest of the diamond works, called Mandango, is situated on the river Jequitinhonha, which in this part is about nine feet deep, and about as broad as the Thames at Windsor. Mr Mawe has minutely described the process by which the diamonds are obtained, the chief object of his visit being to examine the mines. The part of the river which was then worked was a curve or elbow from which the current had been diverted by means of a canal. The deeper parts of the channel were laid dry by means of chain-pumps worked by a water-wheel, and the *cascalho* was then removed by means of machinery. This stratum of debris consists of similar materials to that found in the gold district. During the dry season sufficient *cascalho* is dug up to occupy all the hands during the rainy months. This gravelly matter is washed in troughs placed under sheds erected for the purpose. The negroes are formed into working parties called troops, containing two hundred each, under the direction of an administrator and inferior officers. Besides the precious stone, which is principally sought, gold is found in the debris. Diamonds are by no means peculiar to the beds of rivers or deep ravines; they have been found in cavities and water-courses, even on the summits of the loftiest mountains. They of course vary exceedingly in size. Some are so small that four or five are required to weigh one grain, consequently sixteen or twenty to the carat. There are seldom found more than two or three diamonds of from seventeen to twenty carats in the course of a year; and not once in two years is there found throughout the whole washings a stone of thirty carats. There are other diamond works in this comarca besides Mandango, particularly those of Monteiro, and those situated on the Rio Pardo. Thirty-five leagues from Tejuco, in a north-easter-

Minas Geraes. ly direction, is Tocaya, the principal place in the district of Minas Novas. The road to it runs nearly parallel with the Jequitinhonha, in the numerous rivulets flowing into which river are found white and blue topazes, aqua-marinas, and the chrysoberyl, a stone held in high estimation in Brazil. Twenty-five miles north-north-east of Villa do Principe is the town of Fanado or Bom Succeso, in the neighbourhood of which diamonds of an inferior quality are found. There are several other arraias in this comarca, amongst which may be mentioned Bara do Rio das Velhas, a place of considerable commerce, and, but for its insalubrity, likely to become one of the largest places in the province.

The great river San Francisco is the boundary line between the comarca of Serro do Frio and that of Paracatu. This almost unknown district, prior to 1815, was included in the comarca of Sabara. A new ouvidor was then appointed for the township and circuit of Paracatu, the villages of Desemboque and Araxa being subsequently detached from the comarca of Villa Boa in Goyaz, and annexed to the new ouvidoria. Paracatu do Principe, the only town, owes its origin to its mines, first discovered in 1744. These consist of gold and lead; but diamonds have also been found in some places.

The comarca of Sabara, which formerly included all the western part of Minas Geraes north of the comarca of Rio das Mortes, takes its name from its head town, the Villa Real do Sabara. This town stands near the confluence of the small river of the same name with the Das Velhas, about thirty-five miles north-north-west of Mariana, and is surrounded with mountains. About twelve miles from Sabara there is said to be a tepid lake, two miles in length by one in breadth. It has acquired the name of the Holy Lake, from its waters having been found to possess medicinal virtue in various diseases. Fifteen miles north of Sabara is the flourishing parish of St Luzia, which contains a considerable population, and is ornamented with five Roman Catholic temples. The only towns in the comarca besides Sabara are Villa Nova da Raynha, better known by its Indian name of Caethe, containing about 5000 inhabitants; it is twelve miles east-south-east of Sabara, and has in its suburbs good potteries; and Pitanguí, situated on the right margin of Para, about eighty miles west-north-west of Sabara. Its inhabitants, about 20,000 in number, breed horses, cattle, hogs, and sheep, and cultivate cotton and the sugar-cane.

The comarca of St Joao del Rey or Rio das Mortes occupies the southern extremity of the province adjoining those of St Paulo and Rio. It is itself larger than the whole kingdom of Portugal, and the land is for the most part rich and fertile in a high degree. From March to November the climate is fine and dry, the nights being sometimes sharp and frosty. Ice is occasionally formed, and snow falls, but they disappear before the noon-day sun. About the middle of November the rainy season is ushered in by violent thunder and lightning. Rain comes invariably from the south, and in continued damp weather the air is unpleasantly cold. The Villa St Joao del Rey, antecedently called Rio das Mortes, is a handsome little town, surrounded by a bulwark of romantic hills and broken rocks, with tracts entirely sterile, and others covered with the most luxuriant verdure. Its situation is so agreeable and central, that an intention was once formed of making it the capital. There are in St Joao about 6000 inhabitants, of whom only one third are white people, the rest being negroes and mulattoes. For their employment and support there are no manufactures, except a small one of hats of a peculiar kind. In the adjoining country a large quantity of woollen cloth is made from native pro-

duce, and serves for ordinary clothing. Yet the trade of St Joao del Rey must be considerable; for Dr Von Spix informs us that four constantly employed caravans, each of fifty mules, annually go backwards and forwards to the capital, conveying thither bacon, cheese, some cottons, woollen hats, horned cattle, mules, and gold bars; and bringing back in return European goods, chiefly Portuguese and English, such as calicoes, handkerchiefs, lace, iron-ware, wine, porter, and liqueurs. The gold mine, to which the town owes its origin and celebrity, and whence such masses of mineral wealth have been extracted, is situated within the town. It is nothing more than a deep pit, and is now little resorted to. St Joao del Rey is situated eighty miles south-west of Villa Rica, about the same distance south-south-west of Sabara, and upwards of two hundred miles north-west of Rio. The population of Minas Geraes has been computed at between six and seven hundred thousand inhabitants, of whom nearly a fourth are slaves. Indians are found only upon the eastern confines of the province, or in the impenetrable forests of the Serra do Mar.

MINCHA, in the Jewish customs, offerings of meal, cakes, or biscuits, made in the temple of the Lord. The Seventy-two have sometimes preserved this word in their translation; but instead of *mincha* they read *manaa*, which doubtless was the received pronunciation in their time.

MINCHINHAMPTON, of a town of the county of Gloucester, in the hundred of Longtree, a hundred miles from London. Some parts of the parish are very romantic, especially one called the Golden Vale. The clothing trade forms the chief occupation. Near to it are several elegant seats. The celebrated Roger Bacon was an inhabitant of the town. The population of the town amounted in 1801 to 3419, in 1811 to 3246, in 1821 to 4907, and in 1831 to 5114; but there are two hamlets within the parish, Rodborough and Nailsworth, and the number of the whole inhabitants appears by the last census to have been 7255.

MINDANAO. See MAGINDANAO.

MINDEN, one of the governments into which the Prussian province of Westphalia is divided. It has been formed out of the ancient principalities of Minden, Paderborn, and Corvey, and the smaller sovereignties of Reckenberg, Rheda, and Rittberg. It is divided into thirteen circles, extends over 2068 square miles, comprehends thirty-six cities or walled towns, seven market-towns, and 549 villages, besides many detached agricultural establishments. In 1834 the houses were 48,000, and the inhabitants 407,177, of whom about four sevenths were Protestants, and the remainder chiefly Catholics, with some Jews and a few Menonites. The city of Minden is the capital of the government and of the circle. It is built on the river Weser, over which is a bridge 600 feet long. It is an important pass, and is strongly fortified, the works having of late years been much extended. In 1834 it contained five Lutheran, two Catholic, and one Calvinist church, with 7785 inhabitants. It contains some manufactures of woollen, linen, and iron goods, and some trade by the Weser, which connects it with Bremen. It is known as the field of battle in 1759, where the French suffered a partial defeat. Long. 8. 50. 6. E. Lat. 52. 17. 47. N.

MINDORO ISLE, one of the Philippine Isles, a hundred and ten miles in length, by about twenty-five in average breadth, and situated due south from the south-west extremity of the island of Lucos. The interior is mountainous, but sloping towards the sea-coast; the whole covered with trees, and making a beautiful appearance from the sea-coast. The island is well inhabited, though the Spaniards have a few establishments there. Long. 120. 24. to 121. 24. E. Lat. 12. 21. to 13. 30. N.

Mincha
||
Mindoro.

MINERALOGY.

Mineralogy.

MINERALOGY is that department of Natural History which makes us acquainted with all the properties and relations of minerals. It is divided into two grand branches, viz. Mineralogy properly so called, and Geology. Mineralogy treats of the properties and relations of *Simple Minerals*;

while Geology considers the various properties and relations of the *Atmosphere*, the *Waters of the Globe*, the *Mountain Rocks*, or those mineral masses of which the crust of the earth is principally composed, and the *form, density, heat, electricity, and magnetism of the earth*.

Mineralogy.

I.—MINERALOGY.

1. *System of Arrangement.*

The arrangement of simple minerals has always been a subject of controversy with mineralogists; and the discussions to which it has given rise have materially contributed to the advancement of our knowledge of the natural and chemical history of minerals. Berzelius contends for the Chemical arrangement, according to which the species are grouped in conformity with their chemical composition and characters; Werner rejects the pure chemical, and adopts the Mixed method, in which the species are arranged and determined according to the conjoined external and chemical characters; of late years the plan, or the arrangement according to external characters alone, (named the Natural History System), has been advocated by Mohs; and Jameson, in his lectures in the University of Edinburgh, has for some years taught his pupils according to a method of a mixed character, which, had we space, might be more particularly noticed. The system of Mohs having been formerly adopted in this work, as one founded on correct principles, and, very useful in a practical view, is still adhered to.

2. *Characters of Minerals.*

As the characters employed in the natural history system of mineralogy are principally those named external, our attention will here be chiefly directed to the consideration of their various properties, using the chemical characters only in so far as they illustrate the constituent parts of the mineral species. We shall first give an account of the characters used in the construction of the different principal divisions of the system; and next enumerate and define those characters which are employed in the *description* of the species, sub-species, kinds, and varieties of simple minerals.

I. CHARACTERS EMPLOYED IN THE DETERMINATION OF THE CLASSES, ORDERS, GENERA, AND SPECIES.

1. Regular Form.—2. Cleavage.—3. Hardness.—4. Specific Gravity.¹

I. REGULAR FORM.

1. *Simple and Compound Forms.*

The first step Crystallography takes in the consideration of the regular forms occurring in the mineral kingdom, is to distinguish them into *simple* and *compound* ones. A simple form is contained under *homologous* planes, or such as are equal, similar, and equally disposed in respect to each other; a compound one is contained under planes *not homologous*, or such as are not equal, similar, and equally disposed to each other.

2. *Combinations.*

A compound form is termed a *combination*. The com-

binations consist of the simple forms, and each face occurring in them, belongs to a particular simple form, in as far as it is not homologous with others.

3. *Edges of Combination.*

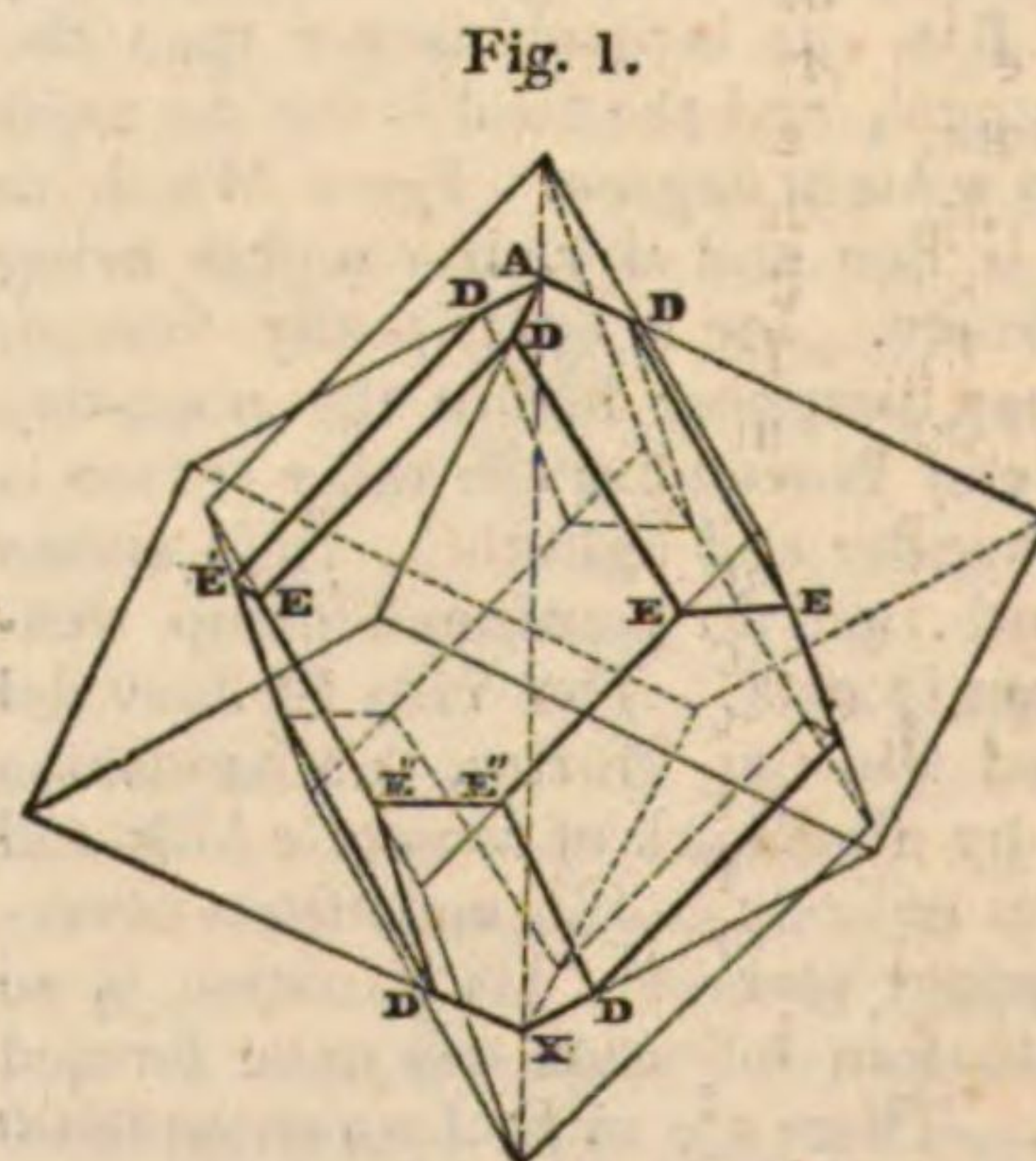
The edges, in which the faces of different forms meet or intersect each other, are called *edges of combination*. The denomination of the edges between the homologous faces depends upon the simple forms themselves, or upon their peculiar situation, and their other qualities.

4. *Development of the Combinations.*

An object of the greatest importance for crystallography is the illustration of the *development* of the combinations. A combination is developed by shewing of what simple forms it consists, and in what relations those simple forms are to each other. The manner in which this is done is as follows: *First*, The connection existing among certain simple forms is exhibited; and these simple forms are arranged accordingly into series, the members of which, between certain limits, follow constant laws, and are known in all their geometrical relations, if it is possible to determine their distance from a known member, or to assign them their relative position in a series, which contains the same member. The position of a member in the series is determined by considering the situation of the edges of combination; and the development of the latter will, therefore, depend upon two points; first, to make out the kind of the simple forms they contain; and, then, from the observed situation of the edges of combination, to determine to which member of the afore-mentioned series they belong, or which places they occupy in the series.

5. *Preparation for the Development of the Combinations.*

Let fig. 1. be a combination of two rhomboids or rhombohedrons.² The faces ADEED, ADE'E'D, ... belong to one, the faces DEE'E'E', ... to the other. Let the edges of combination DE, DE', ... be parallel, and the faces of the two forms that meet in them equally inclined to each other. The plane angles at the apex, or at the solid angle formed by three equal plane angles of the former, are smaller than the same of the latter; and likewise the inclination of the *terminal edges*, or at those



which terminate in the apex, or in the terminal point of the axis AX of the former, is smaller than the same of the latter,

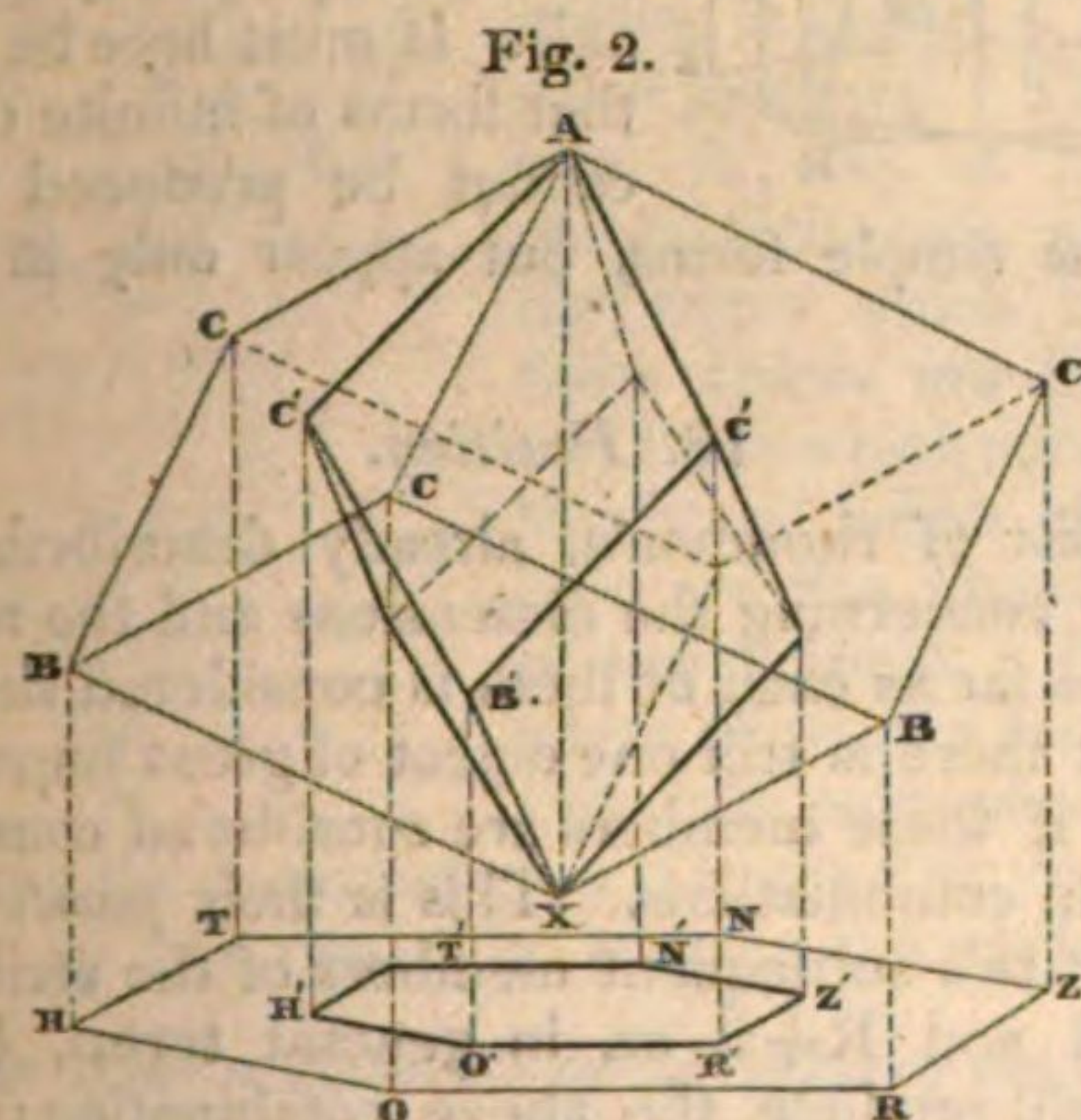
¹ Certain varieties of colour, the lustre, and also the streak, are occasionally used in forming the characters of the systematic divisions.

² We use, as synonymous, the terms rhomboid and rhombohedron.

Mineralogy. which, therefore, is called the *more obtuse*, whilst the former bears the denomination of the *more acute rhomboid*. It would not be sufficiently intelligible to derive the relation which exists between the two rhomboids, from the figure in its present state, the absolute dimensions remaining unaltered. Let, therefore, the axis of the more obtuse rhomboid increase, till it equals that of the more acute one, without any alteration in the angles, and consequently in the parallelism of the edges of combination depending upon them. Whilst the axis increases, that part of the faces of the more obtuse rhomboid, which is visible in the combination, will become narrower and narrower, till it disappears, when the length of the axis is equal in both the forms. The planes of the more obtuse rhomboid are in this case tangent to the terminal edges of the more acute one; and the absolute dimensions are now in that state, in which they allow of a clear development of the relations between the forms which the combination contains.

6. Upright Position and Horizontal Projection.

Place a rhomboid in such a position that its axis is vertical. This is called the *upright position*. From the six angles of the rhomboid, B', C' ..., fig. 2, which are no apices,



draw perpendicular lines B'O', C'R' ... to a horizontal plane, and join the points in which these perpendiculars meet with the plane, by straight lines O'R', R'Z' ... The regular hexagon H'O'R'Z'N'T' produced by those lines is called the *horizontal projection* of the rhomboid.

7. Relation of the Two Rhomboids expressed by the Side of the Horizontal Projection.

By comparing the planes of the horizontal projections HORZNT and H'O'R'Z'N'T' belonging to the rhomboids, we find that, the axes being supposed equal, the horizontal projection of the more obtuse is four times as large as that of the more acute; or it is to the same in the ratio of 4 : 1. From this follows the ratio of their sides = 2 : 1. Therefore, two rhomboids, the horizontal projections of which are in the ratio of 4 : 1, or the sides of these in that of 2 : 1, the axes being supposed equal, will be able to produce a combination in which the edges of combination are parallel to each other; also to the terminal edges of the more acute, and to the inclined diagonals (those which join the apex with the opposite angle of the faces) of the more obtuse rhomboids; provided the absolute dimensions allow the space to be limited by both the forms at the same time. This is one of the relations between simple forms, which are useful and necessary for explaining the combinations, and of which the other relation will be explained in the following paragraphs.

8. Fundamental Form, Derivation, Derived Form.

What has been said above leads to a general method, one form being given or chosen, to find one or several others, which are in such relations to it, as to be fit for ex-

plaining the combinations. The form chosen for this purpose is called the *fundamental form* or *type*; the proceeding by which the other forms are produced the *derivation*, and those forms themselves the *derived forms*.

9. Relation of the Two Rhomboids expressed by the Axis.

The easiest method of expressing the relation of the derived rhomboids to the fundamental form (§ 7.) is not that by the sides of the horizontal projections, the axes being supposed equal. Let, therefore, the derived rhomboid, without any alteration in its angles, diminish in size (as could be done by sections parallel to its faces) till its horizontal projection becomes equal to the horizontal projection of the fundamental form; its axis will decrease to half of its former length. Now, the horizontal projections being supposed equal, the axis of the derived rhomboid will be to the axis of the fundamental form in the ratio of $\frac{1}{2} : 1 = 1 : 2$, an expression of the relation between the two forms, which, on account of its easy application, we shall retain and make use of as we proceed.

10. Inversion of the Proceeding.

The mode of proceeding, by which the more obtuse rhomboid has been derived from the more acute one, can easily be inverted; setting out from the more obtuse one, we can, by the same way, in an opposite direction, derive the more acute rhomboid. The diagonals being drawn upon the faces of the rhomboid, and by planes laid through three and three of them, those parts which are situated on their outside being taken away, what remains will be a rhomboid more acute than the fundamental form. The axes of both these forms are equal, whilst the sides of the horizontal projections in the fundamental and the derived rhomboid are in the ratio of $1 : \frac{1}{2}$. Now, the horizontal projections being equal, the ratio of the axes will be $= 1 : 2$.

11. Generality of the Relations.—Series.

These modes of proceeding, and the relations between the derived forms, are general. If, therefore, from one rhomboid, taken for the fundamental form, another more obtuse has been derived; this same more obtuse rhomboid, considered as a fundamental form, will yield another still more obtuse; and if, on the other hand, from the fundamental form a more acute rhomboid has been derived, the same proceeding applied to the resultant form will give another still more acute; and this may be continued on either side *ad infinitum*. The ratio between the axes of any two subsequent rhomboids, the horizontal projections being supposed equal, has every where the same exponent. The axes are therefore in a geometrical progression, and the rhomboids represented by these axes are themselves said to form such a progression, or a *series*.

12. Laws of Progression of the Series.

Let A be the fundamental form, its axis = a . Let B represent the first, C the second more obtuse; B' the first, C' the second more acute rhomboid, the rhomboids will follow each other thus:

$$\dots C, B, A, B', C' \dots$$

their axes will be

$$\dots \frac{a}{4}, \frac{a}{2}, a, 2a, 4a \dots$$

or they are in the ratios of

$$\dots \frac{1}{4}, \frac{1}{2}, 1, 2, 4 \dots$$

$$\dots 2^{-2}, 2^{-1}, 2^0, 2^1, 2^2 \dots$$

equal to those of the powers of the number 2.

The more obtuse rhomboids B, C ... and the more acute ones, B', C' ... derived from a given or supposed funda-

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mental form A, their horizontal projections being equal, produce a series, in which the axes of the subsequent members increase on one side, and decrease on the other, like the powers of the number 2.

13. Designation.

The method of designating crystallizations, whether simple or compound, is founded on the present and similar series, to be developed afterwards. Represent the fundamental form by any arbitrary letter, in this case, according to the practice hitherto observed, by R. The sign of any other member of the series contains the same letter; the exponent of the fundamental number of the series, which, in the present case, is the number 2, being added for the sake of expressing the place occupied in the series by the number to be designated. This yields the crystallographic sign for one member, and by applying the same proceeding to the others, the designation also of the whole series.

14. Continuation.

The above mentioned part of the series of rhomboids is

C, B, A, B', C';

the ratio of their axes

$$2^{-2}, 2^{-1}, 2^0, 2^1, 2^2;$$

its designation, therefore,

$$R-2, R-1, R, R+1, R+2,$$

and in the same way $R+n$, the general term for each member of the series, which may be transformed into a particular one, by putting whole numbers, positive or negative, instead of n in the expression.

15. Usefulness of the Designation.

From the ratio of the axis to the side of the horizontal projection being known in a rhomboid, all the rest of its ratios, its dimensions (plain and solid angled), &c. can be deduced. The side of the horizontal projection is supposed equal in all the members of the series, and made = 1 in the calculations which refer to the rhomboid. The designation contains therefore, by representing the relation of the axes, every thing required as a basis of calculation; and since it does not require any figures (for instance those of a fundamental form), the letter R signifying by itself a rhomboid, the designation is also evident, and upon this depends the easiness of its application in crystallography.

16. Limits of the Series.

There can be no doubt of n being able to obtain any possible value; or, which is the same, the series may be continued as far as we choose. This produces always new rhomboids, as long as n has a finite value. On one side the axis will increase, if n increase and remain positive; on the other the axes will decrease, if the negative value of n increases. Let n become infinite, the axis will likewise be infinite; let $-n$ become infinite, the axis will be infinitely small. It is clear that the limits of the series will be, on one side, a rhomboid of an infinitely large axis, on the other, a rhomboid of an infinitely small axis, and their several signs must therefore be $R+\infty$ and $R-\infty$; so that

$$R-\infty \dots R+n \dots R+\infty$$

represent the series between its limits.

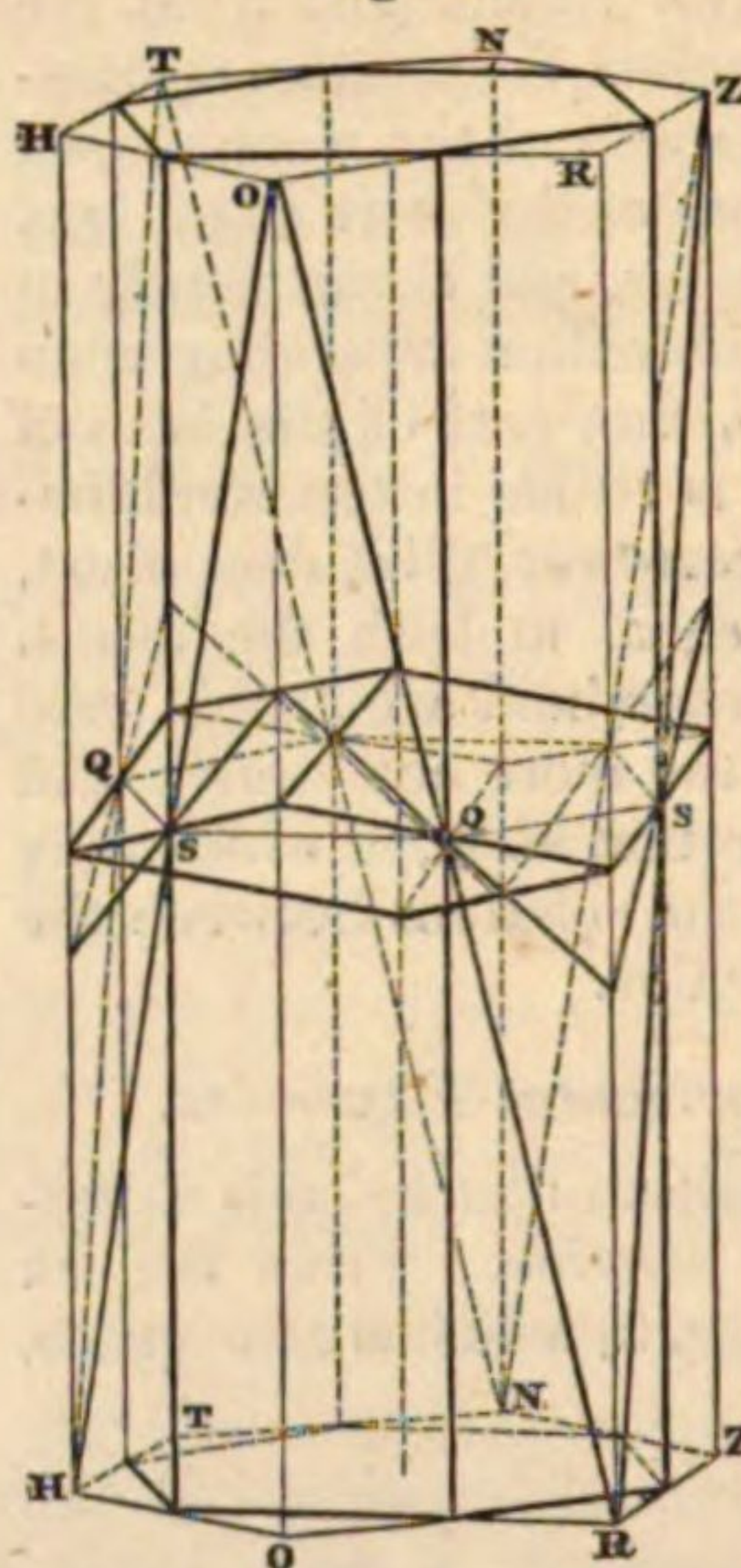
17. The Limits are Regular Six-sided Prisms.

It is very easily shewn that a rhomboid of an infinite axis is a regular six-sided prism; for at the same time, as the axis increases, the six faces of the rhomboid approach nearer and nearer to parallelism with the axis, and they become really parallel with it, if the axis becomes infinitely long. For rendering more evident in what manner the

regular six-sided prism is the limit of the series of rhomboids, we can imagine each face of the rhomboid to make

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Fig. 3.



a revolution round an immoveable line QS, fig. 3. This line is the side of that regular hexagon, which can be inscribed into the horizontal projection HORZNT; the hexagon itself will be the basis or transverse section of the prism, and it differs from the horizontal projection by both its contents and its situation. If the axis of the rhomboid decrease till it ultimately evanesce, the faces contiguous not only to one, but also those contiguous to the other apex, coincide in one plane; and the rhomboid is changed into a plane figure, equal and similar to the horizontal projection, to which it is parallel, and appears, therefore, in all the combinations as a face perpendicular to the axis. It must here be remarked, that forms of infinite dimensions cannot be produced by themselves, or as simple forms, but appear only in combinations.

18. Position.

The series of rhomboids, already described, contains every thing concerning the dimensions and the ratios of its members, as far as each of them is considered singly or by itself. But there is still one object of great importance to be noticed, if those members are considered connected together, or in combinations. This is their *position*. It is evident that two subsequent members of the series, as, for instance, R and $R+1$, or, in general terms, $R+n$ and $R+n+1$, will produce the above combination; in which the edges of combination are parallel, not only with each other, but also with the terminal edges of the more acute; and with the inclined diagonals of the more obtuse rhomboids; but they will produce this combination only in the case of their being in such a position, that the terminal edges of the one are in the same plane with the inclined diagonals of the other, which plane passes at the same time through the axis, as is shewn by fig. 2. This position of two rhomboids is termed the *turned position*, because it arises when a rhomboid is turned out of former position, under an angle of 60° or 180° . If a rhomboid, in the turned position, undergo a new revolution of 60° or 180° , it returns to that which it occupied before, and this is called the *parallel position*. Rhomboids that affect a parallel position with each other, have their terminal edges and their inclined diagonals distributed in such a manner, that the terminal edges of both on one side, and the inclined diagonals of both on the other, fall into one and the same plane, passing through the axis.

19. Position of the Members in respect to each other.

The position of the fundamental form R is considered as the *normal position*, to which those of the derived members are referred. In reference to R , $R+1$ and $R-1$ will be in a turned, $R+2$ and $R-2$ in a parallel, $R+3$ and $R-3$ in a turned position again, and so on; from which it follows, that any two subsequent, or, in general, any two members of the series, between which an even number of members (0 in the above case being considered as even) are wanting, will be in the turned position, whilst any two members of the series, between which an odd number of members are wanting, will affect the parallel position. All

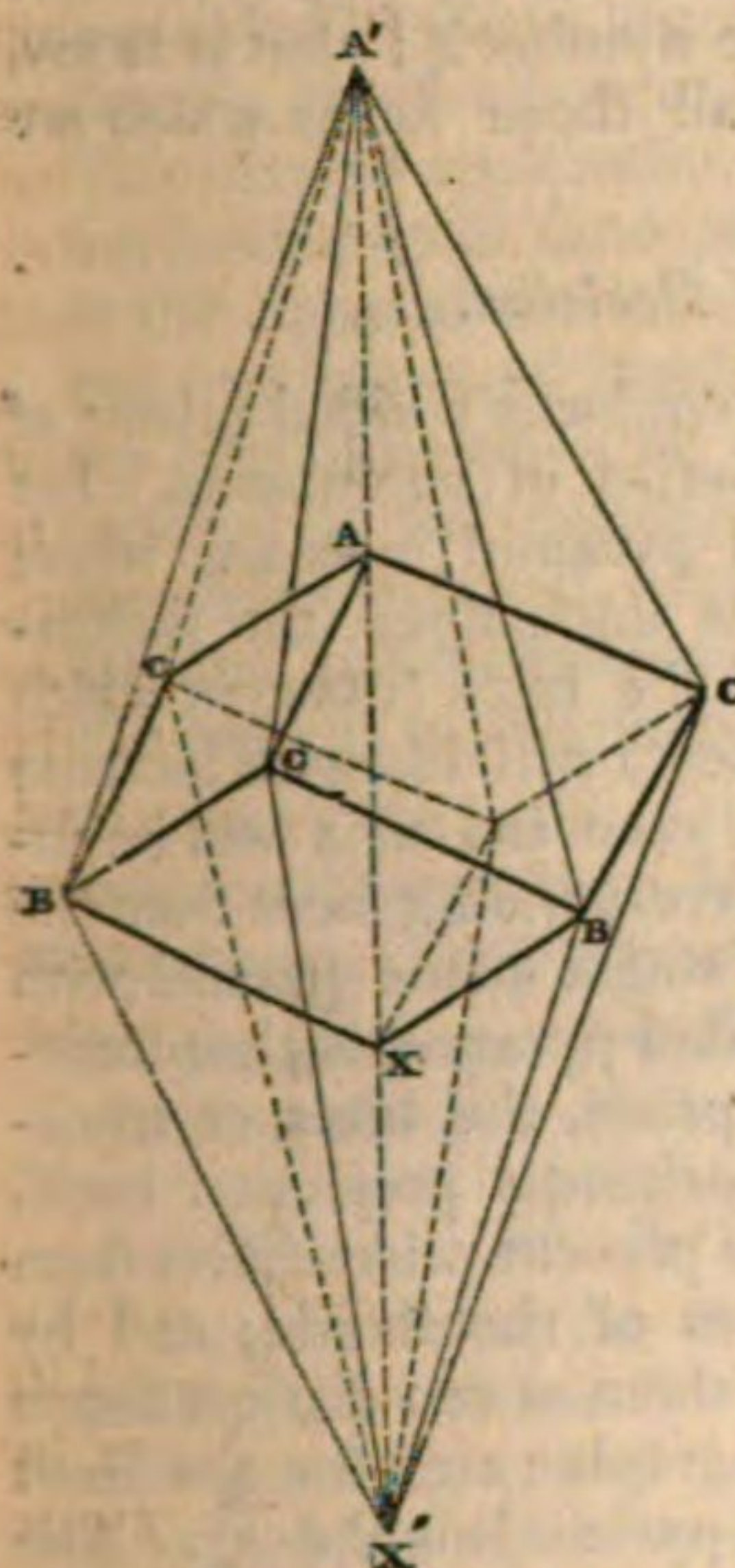
Mineralogy.

those members, therefore, which have their exponent an even number, are in the parallel, those which have their exponent an odd number in the turned position, if compared with R, the fundamental form of the series. The position exercises no influence upon the regular six-sided prism, since, by turning it under angles of 60° and 180° , its faces will come into their former situation.

20. Scalene Six-sided Pyramids.

The rhomboid allows several forms to be derived from it, which are not themselves rhomboids like the original.

Fig. 4.



Lengthen the axis of a rhomboid, fig. 4, on both sides to an indefinite but equal distance, and from the angles B, C, ... draw straight lines to the terminal points A', X', of the lengthened axis. The planes which can be laid through any two contiguous lines of these, and the lateral edges, BC, CB, ... of the rhomboid will produce a form, which, from its faces being scalene triangles, is called a *scalene six-sided pyramid*. The solid angles, A', X', at the terminal points of the axis, are its *apices*; the edges which terminate in these apices are the *terminal*, and those which correspond with the lateral edges of the rhomboid are the *rhomboidal edges* of the pyramid. The terminal edges allow of a farther distinction into *more obtuse* and *more*

acute ones; the faces being on AB, the first, inclined under a greater, on AC, the other, under a less angle.

21. Their Axis a Multiple of the Axis of the Fundamental Form.

Instead of lengthening the axis, we may conceive it to be multiplied by a certain number, expressed in general by m . The values of m must be determined by observation, or, which is the same, they must be derived from combinations containing six-sided pyramids. They cannot, therefore, be fixed arbitrarily, if we expect them to be confirmed by observation.

22. Series of Scalene Six-sided Pyramids.

From each rhomboid, several scalene six-sided pyramids may be derived, and we are authorized to expect as many forms of this kind as observation has discovered different values for m . By deriving scalene six-sided pyramids, according to a constant m , from the subsequent members of the series of rhomboids, a *series of such pyramids* is produced, the axes of which partake of the law followed by those of the series of rhomboids. For the horizontal projections of the pyramids are identical with those of the rhomboids, because the rhomboidal edges of the pyramids have the same situation as the lateral edges of the rhomboids from which they are derived; and the axes of the pyramids, being equal to the axes of the rhomboids, multiplied by a constant number m , will therefore persist in the ratio of those.

23. Designation.

The letter P, in general, signifies a pyramid, but more particularly a six-sided pyramid, if referred to a form derivable from the rhomboid. The quality of a scalene six-sided pyramid, in which there occur differences according to the relation of its axis to that of the rhomboid, must be

made evident by the designation. Include the general sign for the pyramid, expressed in such a manner as to refer to the rhomboid from which it is derived, within crotchets ($\{ \}$), and add the number of derivation, or that by which the axis of the rhomboid has been multiplied, in order to produce the axis of the pyramid, in the form of an exponent; the result will be the crystallographic sign of a scalene six-sided pyramid. Thus $(P+1)^3$ represents a scalene six-sided pyramid derived from R+1 by multiplying its axis by the number 3; and $(P+n)^m$ is the general term of any or of each series of scalene six-sided pyramids, which can be derived from a series of rhomboids having R for its fundamental form, according to the value of m , determined for each particular series. If the axis of the rhomboid from which a scalene six-sided pyramid is derived, and the number of derivation m are known, the dimensions of the pyramid are easily to be found; thus every thing that has been said above (§ 15.) in respect to the designation, can be equally applied in the present case.

24. Values of m .

Although the value of m be, as far as experience goes, most commonly = 2, 3, or 5, yet it sometimes affects others, and even fractionary numbers. The only thing to be said in general of the value of m is, that it must be greater than 1, rational and positive.

25. Limits.

Every series leads to its limits; it is, therefore, to be expected, that the series of scalene six-sided pyramids will have limits of their own. It appears by an easy geometrical construction, that scalene six-sided pyramids, derived according to a constant m , from the different members of a series of rhomboids, or even from any rhomboid though it be no member of that series, if cut perpendicularly upon, and through the centre of their axes; that such pyramids will have a common, or equal and similar transverse section, provided only the horizontal projections of these rhomboids have been equal. This section is an equilateral dodecagon of alternately equal angles. The limits of a series of scalene six-sided pyramids must therefore be a scalene six-sided pyramid of an infinite axis; which, since m cannot become infinite, must be derivable from a rhomboid of an infinite axis, that is to say, from a regular six-sided prism. The limit will, therefore, appear in the shape of an *unequiangular twelve-sided prism*, of the same transverse section, which the finite members of the series produce. Each series of scalene six-sided pyramids is limited by a prism of this kind; the number of different prisms will therefore be equal to the values of m , upon which the angles of their transverse sections depend. The opposite limit, viz. the scalene six-sided pyramid of an infinitely small axis again appears in a plane figure, equal and similar to the horizontal projection, its faces being perpendicular to the axis of those forms with which it is combined. The general sign of an unequiangular twelve-sided prism is $(P+\infty)^m$. The face perpendicular to the axis does not require any particular designation, since that of $R-\infty$ (§ 15) is already applied to it. Respecting the position, both of the scalene six-sided pyramids, and of their limits, the unequiangular twelve-sided prisms to each other, and to the rhomboidal form from which they are derived; §§ 18 and 19 contain the necessary explanations.

26. Subordinate Series of Rhomboids.

There are several rhomboids in connection with R, without being members of the series derived from it, because their axes, the horizontal projections being equal, are not products of the axes of R, multiplied by powers of the number 2. These rhomboids follow, however, the law

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(§ 12) which governs the series of rhomboids immediately derived from R , and their axes are results of the axes of the members of this series multiplied by a certain coefficient. Series arising in this way are termed *subordinate series*, whilst that which has been derived from R has the relative name of the *principal series*.

27. *Coefficients of the Subordinate Series, and how the Members of these belong to each other and to the Members of the Principal Series.*

Members of the subordinate series are geometrically obtained by laying planes into the homologous terminal edges of the scalene six-sided pyramids derived from the members of the principal series, and by enlarging these planes till they enclose the space by themselves. By applying the planes to the more obtuse terminal edges, the resulting

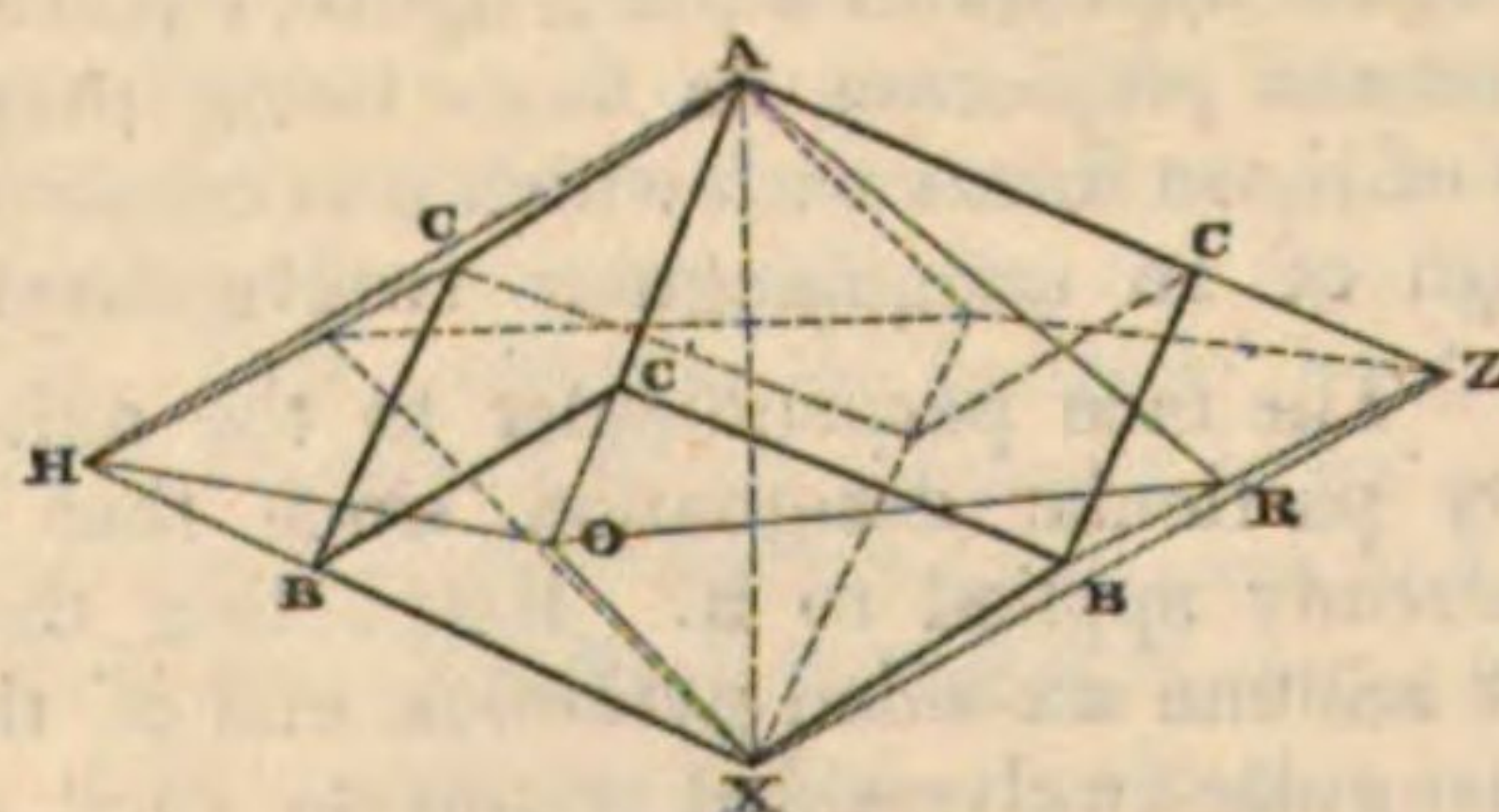
coefficient is $= \frac{3m+1}{4}$; by applying them to the more acute ones, it follows $= \frac{3m-1}{4}$. If the three most common values

of m are one after the other put into the expressions, each of the two coefficients give rise to members of two different subordinate series; but at the same time it yields one member of the principal series, namely, if $3m \pm 1$ becomes equal to a power of the number 2. These numbers of the principal series are not, however, objects of the present consideration. The subordinate series, whose coefficient contains, besides a power of the number 2, the number 5, is styled the *first*; that whose coefficient, also besides a power of the number 2, contains the number 7, the *second* subordinate series. The members of the subordinate series arrange themselves with those of the principal series in such a manner, that the axes of those which are put together stand in the ratio of $1 : \frac{5}{4} : \frac{7}{4}$. According to this disposition, a rhomboid, whose axis contains five-fourths of the axis of $R+n$, or which is $= \frac{5}{4} \cdot 2^n a$, its horizontal projection being equal to that of R , is $R+n$ of the first subordinate series, and its designation $\frac{5}{4}R+n$; a rhomboid whose axis is $= \frac{7}{4} \cdot 2^n a$, is $R+n$ of the second subordinate series, and its designation is $\frac{7}{4}R+n$. Any other value of m affords other subordinate series. The members of a subordinate series cannot be interpolated, or put between those of the principal one, without undoing both these series themselves. The limits of the subordinate series are identical with those of the principal series; the position of their members follows from their derivation.

28. *Isosceles Six-sided Pyramids.*

Apply pairs of planes to the terminal edges AC , of a rhomboid, fig. 5, in such a manner and inclination, that

Fig. 5.



those from the upper apex, AHO and AOR , may intersect those from the under apex, XHO and XOR , in a plane figure $HORZNT$, similar to and parallel with the horizontal projection. The result will be an *isosceles six-sided pyramid*. The axes of both the pyramid and the rhomboid being equal, as appears from the derivation, the sides of their horizontal projections are in the ratio of $3 : 2$. Hence the horizontal projections being supposed equal, the ratio between the axis of the pyramid and that of the

rhomboid will follow $= 2 : 3$, or the first will contain $\frac{2}{3}$ of the axis of that rhomboid from which it is derived. The isosceles six-sided pyramid, derived from $R+n$, is designated only by $P+n$ (§ 23), on account of its being always obtained by a similar proceeding from its rhomboid.

29. *Series of Isosceles Six-sided Pyramids.*

Each member of the principal series of rhomboids has its concomitant isosceles six-sided pyramid of the ratio just stated, the horizontal projections being equal. This gives rise to a series of isosceles six-sided pyramids, the axes of which, their horizontal projections being equal, increase and decrease as the powers of the number 2; that is to say, they follow the general law of all those forms which are derived from the rhomboid.

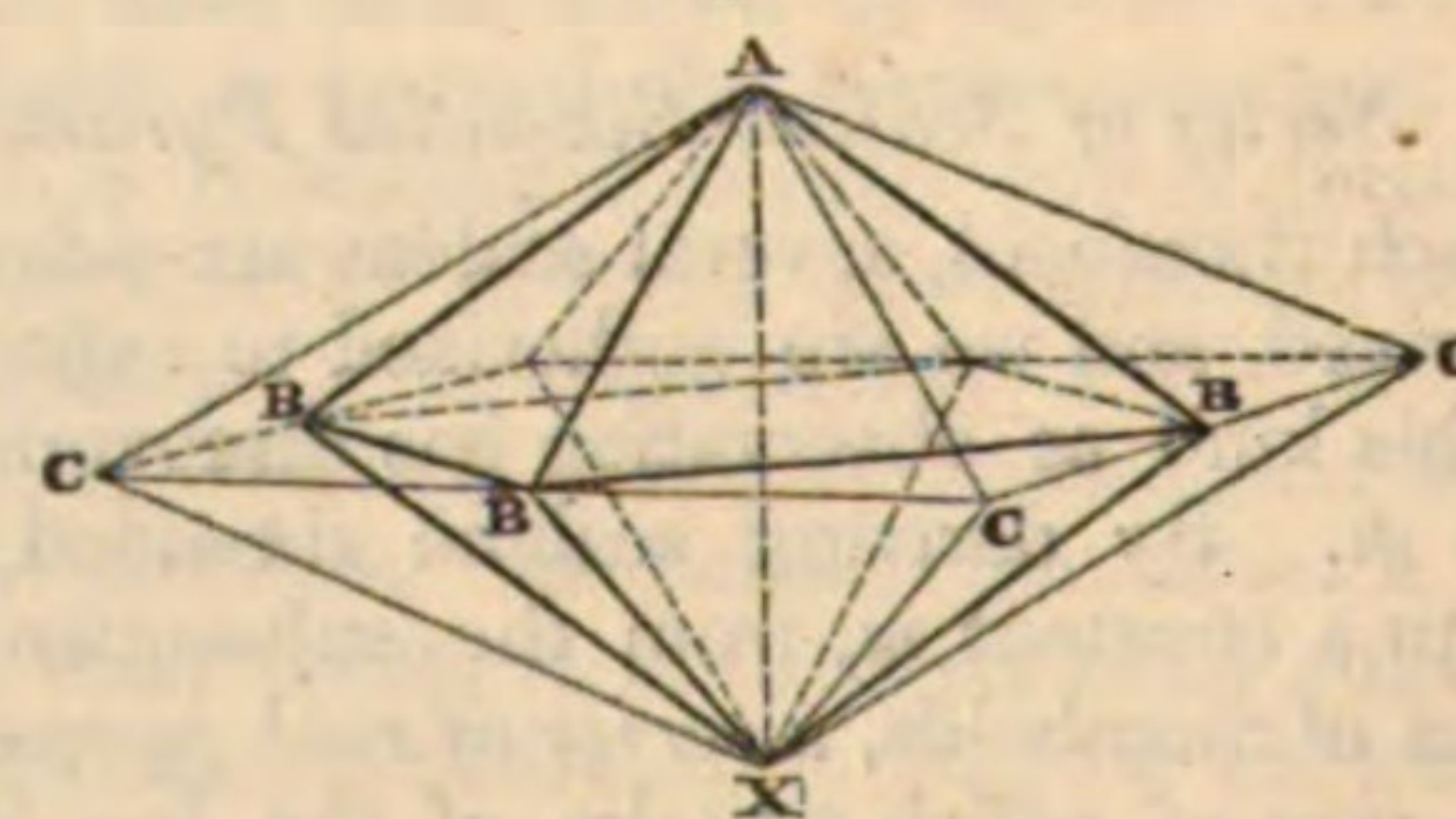
30. *Limits and Position.*

The limits of this series are regular six-sided prisms of infinite axes, like those of the series of rhomboids. Let the axis of an isosceles six-sided pyramid increase, whilst the horizontal projection remains unchanged, the inclination of the faces at the edges of the basis (those in which the faces from different apices meet) will likewise increase till it becomes $= 180^\circ$, in which case the axis will be infinite. In this case, each two corresponding faces from the different apices coincide into a single plane parallel with the axis, and the isosceles six-sided pyramid is thus transformed into a regular six-sided prism, the basis or transverse section of which is the horizontal projection itself. By this basis and its situation the present prism differs from that (§ 17), which limits the series of rhomboids; and by this the necessity of considering them as two distinct forms becomes evident. The crystallographic sign for the limit of the series of isosceles six-sided pyramids is $P + \infty$. The opposite limit, merely a face perpendicular to the axis of any of the foregoing forms, requires no particular designation. Since the faces of an isosceles six-sided pyramid, when this is turned round under 60° or 180° , resume their former situation, there is no difference prevailing in the position of the members and limits of this series, either in respect to themselves, or to the other forms derived from the rhomboid.

31. *Derivation from the Isosceles Four-sided Pyramid.*

Consider an *isosceles four-sided pyramid* (fig. 6), a

Fig. 6.



form contained under eight equal and similar isosceles triangles, as a fundamental form; place it in its upright position, by making its axis AX vertical, and apply to it the process § 5. The tangent planes will limit a space representing again an isosceles four-sided pyramid, the plane angles of which at the apex, and the inclination of the faces at the terminal edges, will be greater than the same in the fundamental form, and hence it will likewise be the more obtuse of both.

32. *Ratio of the Derived Pyramid to the Fundamental Form.*

The axes of these pyramids are equal to each other. The horizontal projection of the more obtuse is that square which can be circumscribed to the horizontal projection of the funda-

Mineralogy. mental form; and, accordingly, its content twice the content of the horizontal projection of the fundamental form, the ratio of their sides $= \sqrt{2} : 1$. Suppose now the horizontal projections of the two pyramids to be equal, the axis of the derived more obtuse pyramid will be to the axis of the fundamental form in the ratio of $\frac{1}{\sqrt{2}} : 1$.

33. Inversion of the Proceeding.

This proceeding can be applied inversely, in order to obtain from the fundamental form the same more acute four-sided pyramid, from which, by the proceeding applied directly, the fundamental form would have been the result. This inverse application is as follows: Draw in the faces of the fundamental form perpendicular lines from the apices to the edges at the basis, lay cutting planes through every two contiguous of these lines, and separate those parts of the pyramids which lie outside of them. The remainder, inclosed by the cutting planes, will be again an isosceles four-sided pyramid, having the same axis as the fundamental form, but a horizontal projection, whose content is half the content of the horizontal projection of the fundamental form, and the ratio of their sides, therefore, $= \sqrt{\frac{1}{2}} : 1$. The horizontal projections being made equal, the axis of the derived more acute pyramid is to the axis of the fundamental form in the ratio of $\sqrt{2} : 1$, which is the inverse of the ratio deduced above.

34. Series and Designation.

By continuing the derivation, the more obtuse pyramid produces another still more obtuse; the more acute another still more acute, and thus arises a series of isosceles four-sided pyramids, whose axes, their horizontal projections being equal, increase and decrease as the powers of the square root of 2; which law of progression can be expressed by $2^{\frac{n}{2}}$ or $\sqrt{2}^n$. The designation of this series is concordant with the principles already laid down and followed (§ 13). The fundamental form receives the letter P. Hence its neighbouring members will be

... P-2, P-1, P, P+1, P+2, ...

their axes that of P being = a,

... $\frac{a}{2}$, $\frac{a}{\sqrt{2}}$, a, $a\sqrt{2}$, $2a$; ...

their ratio to each other,

... $\sqrt{2}^2 + : \sqrt{2}^1 : \sqrt{2}^0 : \sqrt{2}^{-1} : \sqrt{2}^{-2}$; ...

and P+n the general term of the series, which, by the substitution of any whole positive or negative number in the place of n, gives a certain determined member. The present designation is quite the same as that in § 28, and as another to be mentioned in § 44. However, the observation in page 135 is sufficient to shew the impossibility of any confusion or ambiguity that could arise from making use of identical signs for the expression of different forms.

35. Limits.

If n becomes greater or smaller than any given number, a transformation takes place similar to that by which the isosceles six-sided pyramid gave rise to the regular six-sided prism: the series of isosceles four-sided pyramids terminates on one side in an unlimited four-sided prism, on the other in a plane figure, equal, similar, and parallel to the horizontal projection, and these two forms represent the limits of the series. In respect to the first, however, there occurs the particular circumstance, that the series is doubly limited; because the different members in their succession assume a different position. The derivation shews the pyramids, P-1 and P+1, to stand in such a

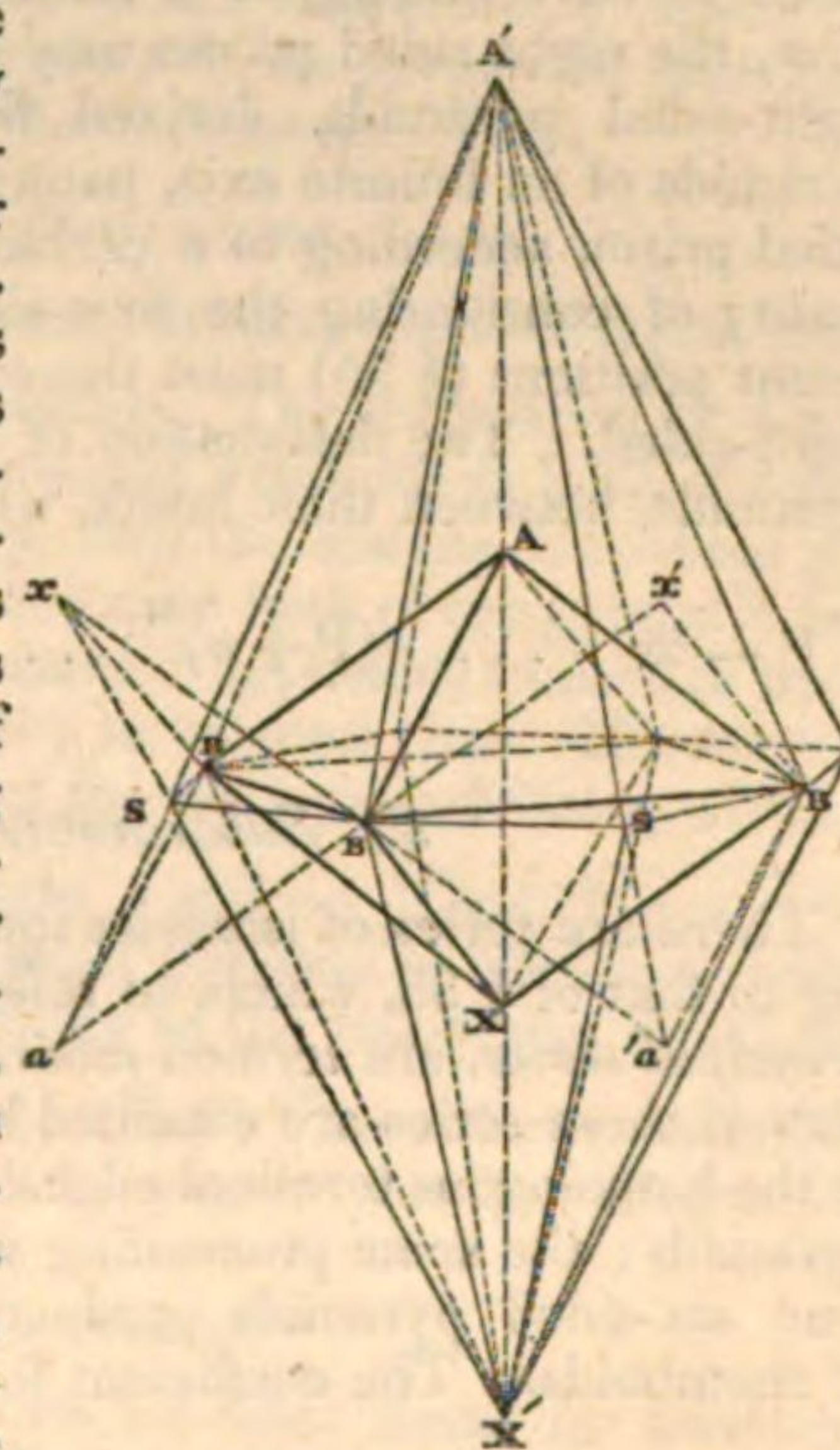
position towards P, that the sides of their bases are parallel with the diagonals of the basis of P; whilst in P-2 and P+2, the sides and the diagonals are parallel with the same lines in the basis of the fundamental form. The former are said to be in a *diagonal*, the latter in a *parallel* position with P; and every thing contained in § 18 and § 19, in respect to position, may be applied here, if only, instead of 60° and 180°, a revolution of 45° is imagined. Suppose now the two different prisms, the regular six-sided, as well as the rectangular four-sided, in both their peculiar positions. The faces of the first will, after having been duly turned, assume their former situation, which is not the case in the second; and hence it becomes necessary to adopt two rectangular four-sided prisms of an infinite axis as limits of the series of isosceles four-sided pyramids, one being in a parallel, the other in a diagonal position with P. The sign of the first is P+∞, that of the second [P+∞]. The opposite limit, where there is no difference in the position, is represented by P-∞; and the whole series of isosceles four-sided pyramids between its limits appears thus,

$$P-8 \dots P+n \dots \left\{ \begin{array}{l} P+\infty \\ [P+\infty] \end{array} \right\}$$

36. Scalene Eight-sided Pyramids.

With the isosceles four-sided pyramids there are connected *scalene eight-sided pyramids*, contained under sixteen equal and similar scalene triangles (fig. 7). These eight-sided

Fig. 7.



pyramids depend upon the four-sided by the same process of derivation, by which the scalene six-sided pyramids take their rise from the rhomboid. The application of this process to the isosceles four-sided pyramid supposes, however, a preparation of this form, which is effected by enlarging its faces beyond the edges of its basis, and by drawing in these enlargements triangles, equal and similar to the faces of the pyramid. Thus the points a, a', ... x, x' ... are fixed in two squares that are perpendicular to the axis AX, in its terminal points, or in the apices of the pyramids. Now, produce the axis of the pyramid on both sides to an indefinite but equal length, or multiply it by a number m, greater than 1 positive and rational (§ 24.) Join, then, the upper terminal point A' of the lengthened axis with the points a, a' ... in the under, the under terminal point X' with the points x, x' ... in the upper square, by straight lines. The points SS' ..., in which these lines intersect each other, will lie in the prolongation of the basis of the four-sided pyramid. We now join these points with the neighbouring angles of the base by straight lines, the result of which will represent the basis of the derived scalene eight-sided pyramid, which may now be completed without difficulty. The most common, though not the only values given for m by nature, are 3, 4, and 5.

37. Series of Scalene Eight-sided Pyramids.

If the number of derivation m be constant, the resultant scalene eight-sided pyramids have similar bases, the axes of the isosceles four-sided pyramids may be whatever they

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will. The application of the described proceeding to the subsequent members of the series of isosceles four sided pyramids will, therefore, m remaining for all the members the same, not only produce a series of scalene eight-sided pyramids, subject to the law followed by the isosceles four-sided pyramids, which is that of $\sqrt{2}$; but the bases or transverse sections of all the members of this series will be similar to each other. The designation of an indeterminate n th member of such a series is $(P+n)^m$, and it is evident, that as many values of m as experience gives, so many different series of scalene eight-sided pyramids will arise.

38. Limits.

The limits of those series are, on one side unlimited unequiangular eight-sided prisms, the transverse sections of them being similar to the bases of the members of the series; on the other side, a plane figure, which in the combinations appears as a face perpendicular to the axis. This is evident from what has been said above, and there remains only to be added, that the prisms of an infinite axis coming into consideration in two different positions, they must be taken for two different forms, or as double limits of the series. These two positions are the *parallel* and the *diagonal*, as in § 35; the parallel being that which prevails between scalene eight-sided pyramids and that isosceles four-sided from which they are derived; whilst forms of this kind in the diagonal position are supposed to have undergone a horizontal revolution of 45° . Now, the eight-sided prisms may be considered as scalene eight-sided pyramids, derived from isosceles four-sided pyramids of an infinite axis, namely, the rectangular four-sided prism, according to a certain value of m . The necessity of considering the four-sided prism in m two different positions (§ 35) must therefore be extended to the eight-sided. The designation of the series of eight-sided pyramids, between their limits, will accordingly be thus:

$$P - \infty \quad \dots \quad (P+n)^m \quad \dots \quad \left\{ \begin{array}{l} (P+\infty)^m \\ [(P+\infty)^m] \end{array} \right\}$$

39. Subordinate Series.

There are series of isosceles four-sided pyramids belonging to that of § 33, which, in reference to the latter, or the *principal series*, are termed *subordinate series*. The members of these series are obtained by placing tangent planes in the homologous terminal edges of the scalene eight-sided pyramids; the same proceeding which applied to the scalene six-sided pyramids produced the subordinate series of rhomboids. The coefficient for the more obtuse terminal

edge (if $m \geq 1 + \sqrt{2}$) is $= \frac{m+1}{2}$; that for the more acute one (under the same supposition) $= \frac{m}{\sqrt{2}}$. If m be

determined, each of those coefficients gives a member of a particular series. The members of the principal and of the two subordinate series arising from $m = 3, 4$, and 5 ,

arrange themselves thus: $1 : \frac{3}{2\sqrt{2}} : \frac{5}{4}$; and are said to

belong together in this order. An isosceles four-sided pyramid, therefore, whose axis, the horizontal projection being equal to that of P , is $= \frac{3}{2\sqrt{2}} \sqrt{2}^n a$ represents the mem-

ber $P+n$ of the first subordinate series, and bears the designation of $\frac{3}{2\sqrt{2}} P+n$; and a similar pyramid, the other

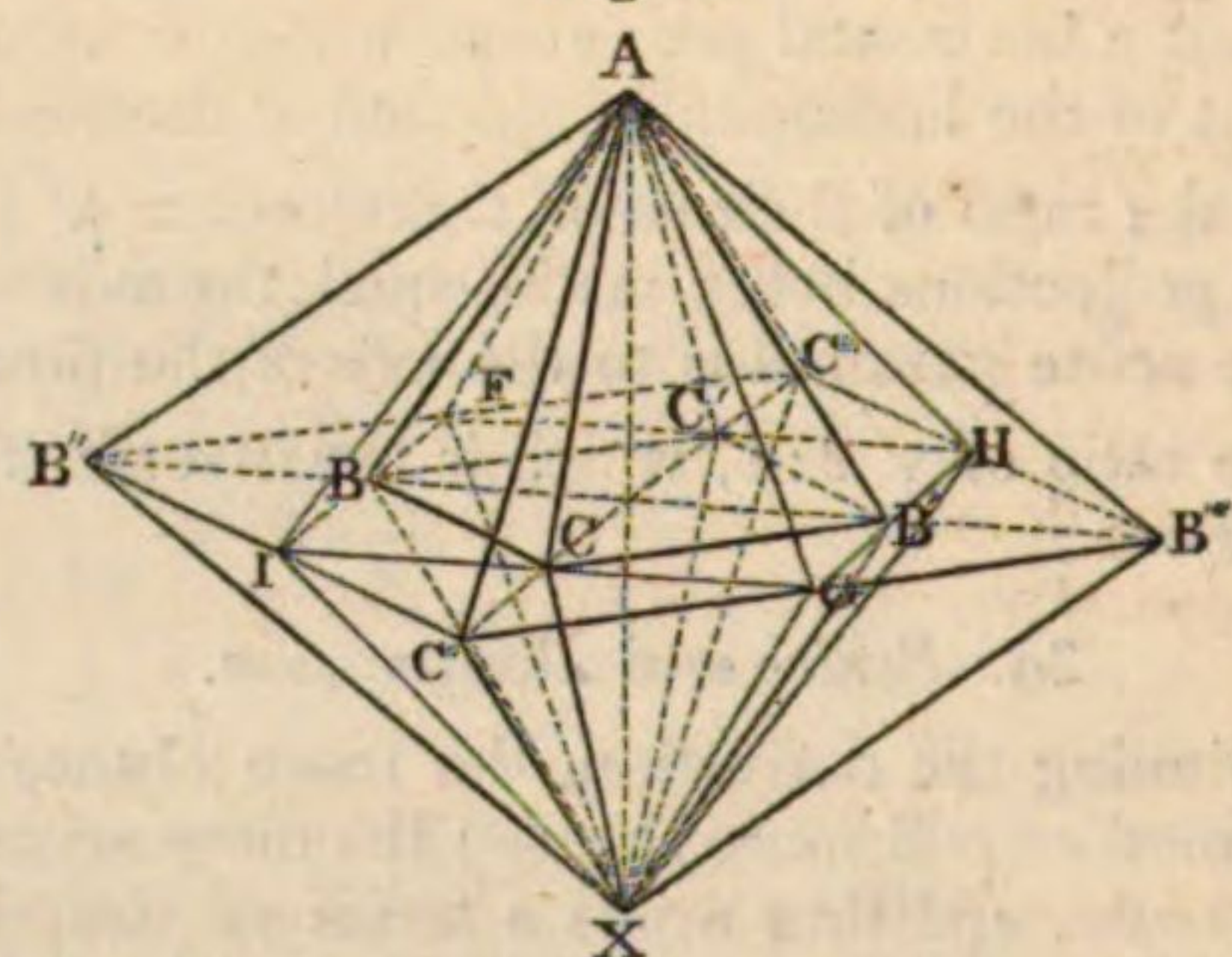
circumstances remaining the same, with an axis $= \frac{5}{4} \sqrt{2}^n a$ is the member $P+n$ of the second subordinate series, ex-

pressed by the designation $\frac{5}{4} P+n$. The limits of the present series coincide with those of the principal series. The positions of its members in respect to each other, and to the members of the principal series, will become evident by comparing what has been stated of their derivation with § 27 regarding the position of the subordinate series of rhomboids.

40. Scalene Four-sided Pyramids.

If in the basis of an isosceles four-sided pyramid, the diagonals are supposed unequal, the pyramid itself is transformed into a *scalene four-sided pyramid*, or into one whose basis is a *rhomb*, its faces *scalene triangles*, and its terminal edges of a different magnitude, the one more obtuse, the other more acute, as is represented by ABCB'C'X, fig. 8.

Fig. 8.



From this we may conjecture that several of the preceding methods of derivation, though with some modifications, will also in this case be applicable.

41. Derivations from it. Auxiliary Form.

Apply to the *homologous* terminal edges of a scalene four-sided pyramid tangent planes, and enlarge them till they intersect each other in every possible direction; the result will be no form limited on every side, or such as is finite in all its dimensions. If the tangent planes are laid in *all* the terminal edges of the fundamental form, a form limited from every side will indeed appear, but this form is *not* a *simple* one, its faces being homologous only by four and four (§ 1). The form thus arising represents a four-sided pyramid, with an *oblong rectangular* basis, AIGHFX, fig. 8; and most of the crystallographers consider it as such, and term it accordingly. In this place it must be considered only as an *auxiliary* or *intermediate* form, which is not the derived form itself, but useful and auxiliary for its derivation.

42. Derived Form.

Suppose tangent planes to be laid in the terminal edges of the *auxiliary form*, in such an inclination that those from the upper apex produce by their intersection with those from the under apex, a rhomb similar and parallel to the basis of the fundamental form, and situated in the prolongation of this basis. The result will be a scalene four-sided pyramid, the basis of which is similar to that of the fundamental form; but the plane angles at the apex, and the inclination at the terminal edges, being greater than in this form, the derived will be more obtuse than the fundamental form.

43. Ratio to the Fundamental Form.

The two pyramids, as produced by the derivation, have the same axis, the ratio between the basis of the derived,

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and the basis of the fundamental pyramid being that of 4 : 1. This ratio is evident, since the basis of the auxiliary form is double of the basis of the fundamental form, and that of the derived form again double of the basis of the auxiliary form. Hence the horizontal projection of the two forms being supposed equal, the ratio between the axes of the derived, and of the fundamental pyramid, is that of $\frac{1}{2} : 1$. The process of derivation, by which the more obtuse pyramid is produced, is liable to an inversion like that in § 10.

44. Series. Designation. Limits. Position.

From a continued derivation on both sides of the fundamental form, a series of scalene four-sided pyramids, of equal and similar bases, will evidently arise, the axes of which increase on one side and decrease on the other, like the powers of the number 2. $P + n$ will be the sign of an indeterminate n th member of the series, and if n becomes infinite, the series reaches its limits, which are on one side an obliquangular four-sided prism, whose transverse section on the other side is a horizontal plane, whose figure is equal and similar to the horizontal projection of the fundamental form. The designation of the series between its limits becomes thus:

$$P - \infty \dots P + n \dots P + \infty.$$

It must be remarked, that such differences on account of the position of the members of the series as are met with in the rhomboid (§ 18) and the isosceles four-sided pyramid (§ 35), are not to be found in the scalene four-sided pyramid.

45. Further Derivations.

The members of the present series are, or this series itself is, now the foundation of several other derivations; and although the forms derived by them will be nothing but scalene four-sided pyramids and obliquangular four-sided prisms, yet the variety in the relations of those forms is great enough to surpass that of the forms in connection with the rhomboid, and with the isosceles four-sided pyramid, for which reason it is one of the most interesting objects of crystallography. The derivations already mentioned apply as well to the fundamental form itself as to the auxiliary form; and they are similar to that which has been employed in deriving the scalene eight-sided from the isosceles four-sided pyramid.

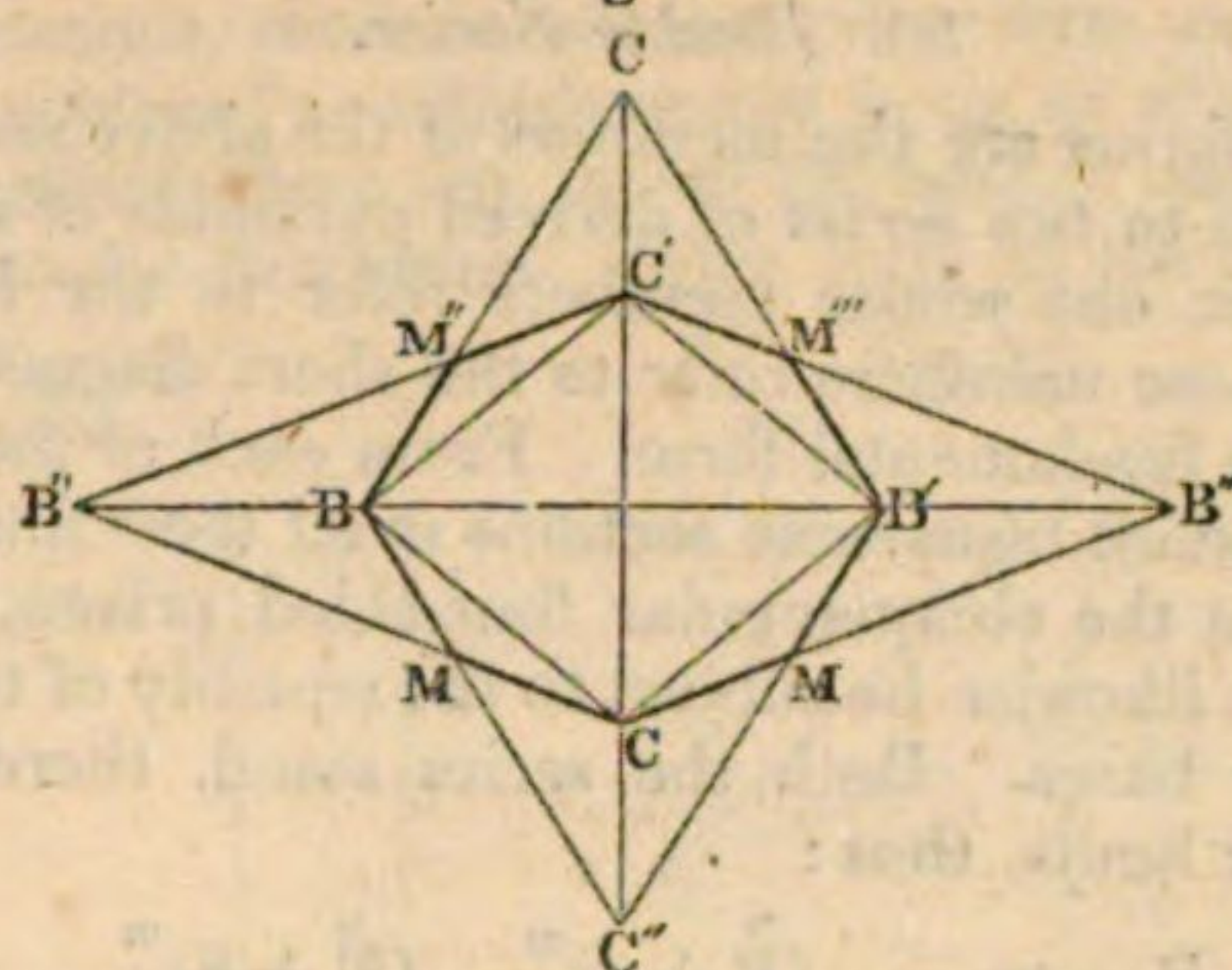
46. From the Fundamental Form.

Instead of the isosceles (§ 37), suppose the scalene four-sided pyramid to be the fundamental form, and prepare it for derivation by enlarging its planes beyond the edges at the basis, and by drawing triangles equal and similar to the faces of the pyramid in these enlargements. The points $a, a' \dots x, x' \dots$ will no longer be the angles of squares, but of oblong rectangles, the planes of which are perpendicular to the axis AX in its terminal points. Produce now the axis of the scalene four-sided pyramid on both sides to an indefinite but equal length, or, what comes to the same, multiply it by a number m , enjoying the general properties mentioned, §§ 24, 26. Draw straight lines from the points $a, a' \dots$ in the lower rectangle to the upper apex A' , from the points $x, x' \dots$ in the upper rectangle to the under apex X' of the lengthened axis, and join their intersections $s, s' \dots$ in the plane of the enlarged basis by straight lines with the angles of this basis. The resultant octagon will not have alternately equal angles, like that in § 36, which is the basis of the scalene eight-sided pyramids, but it will be irregular, fig. 9, since of the angles B, B', c, c' , only the opposite are equal to each other. A form constructed upon such a basis cannot be contained under equal and similar planes, or it cannot be a simple form. Like the four-sided pyra-

mid of an oblong rectangular basis, it is considered as an

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Fig. 9.



auxiliary or intermediate form, whose resolution gives the simple forms of which it consists.

47. Resolution of the Auxiliary Form.

This resolution is executed by enlarging those places which are equal and similar to each other, till the rest disappear. In the present case, the resolution produces two different scalene four-sided pyramids of equal axes, their bases being different amongst themselves, as well as from the bases of the fundamental form. They are termed *scalene four-sided pyramids of dissimilar bases, derived from the fundamental form*, and more particularly that in which the long diagonal of the fundamental form remains unaltered, the *pyramid belonging to the long*: that in which the short diagonal remains unaltered, the *pyramid belonging to the short diagonal of the fundamental form*.

48. Designation.

This important difference between the two forms must be expressed by the designation. The designation $(P + n)^m$ used for the scalene eight-sided pyramids in § 37, if referred to forms in connection with the scalene four-sided pyramids, denotes at the same time both of the pyramids just mentioned. In order to make it applicable to each of them singly, it is now necessary to express their difference in respect to the diagonals of the fundamental forms, which is effected by adding the signs $+$ and $-$. Thus $(P + n)^m$ represents a scalene four-sided pyramid of dissimilar basis, derived from $P + n$ according to the number m , which belongs to the long diagonal; $(\bar{P} + n)^m$, another pyramid of the same properties which belongs to the short diagonal of P .

49. Ratios.

The pyramids just mentioned differ from the members of the series (§ 44), 1st, in their axes, which, the axis of P being $= a$, are expressed by $2^n m a$; 2d, by the ratio of the diagonals of their bases. Let in P the ratio of the axis to the long and to the short diagonal be that of $a : b : c$, or the ratios of the same lines in $P + n$ that of $2^n a : b : c$; the ratio of the homologous lines will be

$$\text{in } (\bar{P} + n)^m = 2^n m a : b : m c,$$

$$\text{in } (\bar{P} + n)^m = 2^n m a : m b : c,$$

as follows easily from the consideration of a few triangles in the figures required for explaining the derivation. Hence the ratio between the diagonals of the bases in the derived forms, that of the fundamental form remaining constant, depends only upon the number m . Accordingly, if m be supposed constant, all the pyramids of this kind, derived from scalene four-sided pyramids of similar bases, will likewise, as far as they belong to one or the other diagonal, contain similar bases or transverse sections, the axes of the

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forms, subservient to the derivation, may be whatever they will.

50. *Double Series.*

If those forms are the members of the above series, each m gives rise to *two series* of derived pyramids of a dissimilar basis, viz. one whose members refer to the long, and another whose members refer to the short diagonal of the basis of the fundamental form. From each of those series having constant transverse sections in all their members, it appears that the obliquangular four-sided prisms, limiting them, must likewise be subject to the equality of transverse sections or bases. Both the series stand, therefore, between their limits, thus:

$$P - \infty \dots (\bar{P} + n)^m \dots (\bar{P} + 8)^m$$

$$P - \infty \dots (P + n)^m \dots (P + 8)^m$$

What has been observed in § 44 in respect to position, may be equally applied here. The values of m hitherto most commonly, though not exclusively observed, are $= 3, 4, 5$. But neither in this case are they the only ones.

51. *Derivations from the Auxiliary Form, § 41. Ratios of the Series.*

Instead of the fundamental form P , or of $P + n$, suppose the auxiliary or intermediate form, belonging to it, to take its place; by applying to it the proceeding described in §§ 46, 47, the form produced in a compound one like that in § 46, but its resolution yields again two simple forms, which are also *scalene four-sided pyramids, whose bases are dissimilar to those of the fundamental form*. These pyramids can be distinguished from each other by referring, the one to the long, the other to the short diagonal; from those derived in § 47, by the form to which the derivation is applied, since, in § 47, it is the fundamental form itself, in the present case, the auxiliary form belonging to it; which latter circumstance is expressed in the crystallographic sign by the letter r added to P . From the dimensions of the three lines disposed perpendicularly to each other in the pyramid $P + n$, the axis and both the diagonals, being in the ratio of $2^n a : b : c$, it will follow, the ratio of the homologous lines in the scalene four-sided pyramids of dissimilar basis, derived from the auxiliary form, which belongs to the long diagonal of the fundamental form, or in

$$(\bar{P}r + n)^m \text{ to be } = \left(\frac{m+1}{2}\right) \cdot 2^n a : b \quad \left(\frac{m+1}{m-1}\right) c,$$

$$\text{in } (\bar{P}r + n)^m = \left(\frac{m+1}{2}\right) \cdot 2^n a : \left(\frac{m+1}{m-1}\right) b : c.$$

The dependence of the ratios between the diagonals of the basis, only from m , is evident; and this remains unaltered, how much soever a and n may be allowed to vary. If the derivation is applied to the whole series in § 44, there will arise two series of scalene four-sided pyramids, which proceed according to the law of the fundamental series, and are limited by obliquangular four-sided prisms, partaking of the similarity in the transverse sections of all the members. The crystallographic designation of the series, between their limits, stands thus:

$$P - \infty \dots (\bar{P}r + n)^m \dots (\bar{P}r + \infty)^m$$

$$P - \infty \dots (\bar{P}r + n)^m \dots (\bar{P}r + \infty)^m$$

The values of m are here the same as in the above-mentioned cases. To the position applies what has been said in § 44.

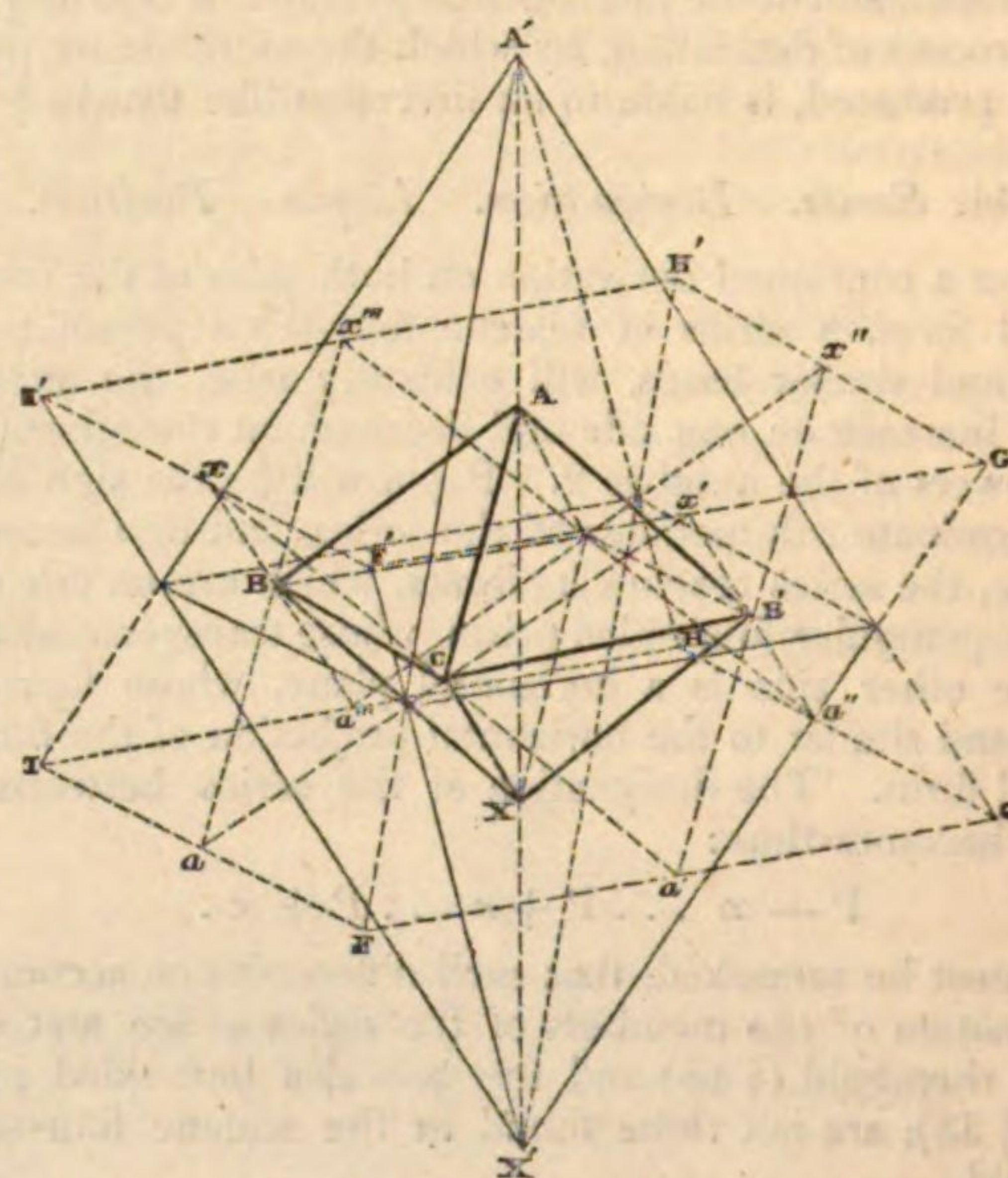
52. *Subordinate Series.*

That there are certain *subordinate* series belonging to the series § 44, which, in reference to the former, may also be considered as the principal series, can easily be suppo-

sed from the agreement existing between the forms derived from the scalene, and those derived from the isosceles four-sided pyramid. In order to obtain the members of these subordinate series, enlarge the faces of the fundamental form, fig. 10, on both sides; draw in the enlarged faces

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Fig. 10.



triangles, equal and similar to the faces of the fundamental form; through the point $a, a' \dots x, x' \dots$, thus determined, lay rhombs, similar and parallel to the basis of the fundamental form; multiply the axis by a number m ; join the points X', A' , of the lengthened axis by straight lines with the said points $a, a' \dots x, x'$; and, lastly, reduce the derived pyramid which has a basis similar to that of the fundamental form, to an equal horizontal projection with it. The number m being not yet determined, the coefficient of the subordinate series will be $= \frac{m+1}{2}$; which, if $m+1$ be equal to any power of the number 2, shews the member to which it belongs to be a member of the principal series. The subordinate series, whose coefficient, besides powers of the number 2, contains the factor 3, is termed the *first*, and that which, in the same case, contains the factor 5, the *second* subordinate series. Members of the principal, of the first and of the second subordinate series, which are supposed to belong together, arrange themselves thus: $1 : \frac{3}{4} : \frac{5}{4}$, which numbers express the ratio between their axes. The designation and the position of the members in the subordinate series is evident from the foregoing.

53. *Resolution of the Auxiliary Form, § 41. Horizontal Prisms.*

The only form now left for examination is the auxiliary form, § 41; which, as has been mentioned above, is not a simple one, its faces not being homologous. By enlarging only those planes which, amongst themselves, are equal and similar, there arise *two obliquangular four-sided prisms*, unlimited in the direction of their axis, and which, therefore, like all the prisms, are forms in which one dimension is infinite. The axes of the two prisms are perpendicular to each other, and have a horizontal position, if the fundamental form be in the upright position. These axes coincide with the diagonals of the basis of the fundamental form produced to an infinite length. Hence the prisms may be considered as scalene four-sided pyramids, one diagonal of which has become infinite; similarly to the *vertical* prisms, that are scalene four-sided pyramids of an infinite axis. For the sake of distinguishing them from these, they bear the

Minera- name of *horizontal* prisms, and their general designation is
logy. $\text{Pr} + n$. More particularly, $\text{Pr} + n$ expresses the horizon-
tal prism in which the longer diagonal, $\text{Pr} + \infty$ that in
which the shorter diagonal of the fundamental form has re-
mained a finite quantity.

54. Series of Horizontal Prisms.

Every scalene four-sided pyramid, whatever its properties may be, has its dependent horizontal prisms. To every series of such forms will, therefore, belong two series of horizontal prisms, to be distinguished by their designation according to the properties of those series. It is, however, remarked, that, if we take the common values of m , as stated above, the angles of several members of those series, and, therefore, the series themselves, will be identical; and, for this reason, one designation will suffice for them. Thus, the number of series of those forms taken together may be reduced to three pairs, of which the first pair belongs to the principal, the others to the subordinate series of scalene four-sided pyramids; each of the diagonals having one series referred to it. The horizontal prisms belonging to a scalene four-sided pyramid are produced by placing tangent planes in its *homologous* terminal edges. If those terminal edges connect the terminal point of the axis with the long diagonal, the prism is said to belong, or to be referred, to the long; if they connect it with the short, it is said to belong, or to be referred, to the short diagonal of P. The horizontal prisms are remarkable forms, often to be met with in the natural combinations.

55. Limits of the Series of Horizontal Prisms.

By comparing the horizontal prisms belonging to members of a series of scalene four-sided pyramids, it becomes evident how, whilst the axis of the pyramid increases, the angle of the horizontal prism contiguous to the axis of the fundamental form becomes smaller and smaller; whilst the other, at the intersection of the planes from different apices, becomes greater and greater. If the axis of the pyramid become infinite, or the pyramid itself a vertical prism, the first of these angles will disappear, the second become $= 180^\circ$. Hence a horizontal prism is transformed, in this case, in a pair of unlimited parallel planes, perpendicular to the diagonals to which they belong. These planes, which may be considered as forms unlimited, as it were, in two directions, are the limits of the series of horizontal prisms, the axis of the pyramid to which they belong being infinite. The opposite limits, or those which appear, if the pyramid have an infinitely small axis, appear as faces perpendicular to the axis. The series of horizontal prisms between their limits may, accordingly, be represented thus:

$$P - \infty \dots \text{Pr} + n \dots \text{Pr} + \infty$$

$$P - \infty \dots \text{Pr} + n \dots \text{Pr} + \infty.$$

For, having the designation in every respect complete, the coefficient of the series to which the horizontal prism belongs must be added to the sign for a particular member.

Although this is not a place for entering into the examination of combined forms, yet that peculiar combination which is produced by the two limits of the series of horizontal prisms, and takes the appearance of a vertical rectangular four-sided prism, not yet limited in the direction of its axis, cannot remain unnoticed. This combination is

designated by $\text{Pr} + \infty \cdot \text{Pr} + \infty$; it must carefully be distinguished from the rectangular four-sided prisms, limiting the series of isosceles four-sided pyramids, which, abstraction being made of the face perpendicular to the axis, are simple forms; a property not belonging to the rectangular prism in connection with the scalene four-sided pyramid.

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56. Derivations from the Hexahedron.

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logy.

Besides the rhomboid, the isosceles, and the scalene four-sided pyramids, there is only one other form existing fit for being considered as a fundamental form, or which, without being derivable from any one of the former, can itself serve as basis to the derivation. This form is the *hexahedron*,

Fig. 11.

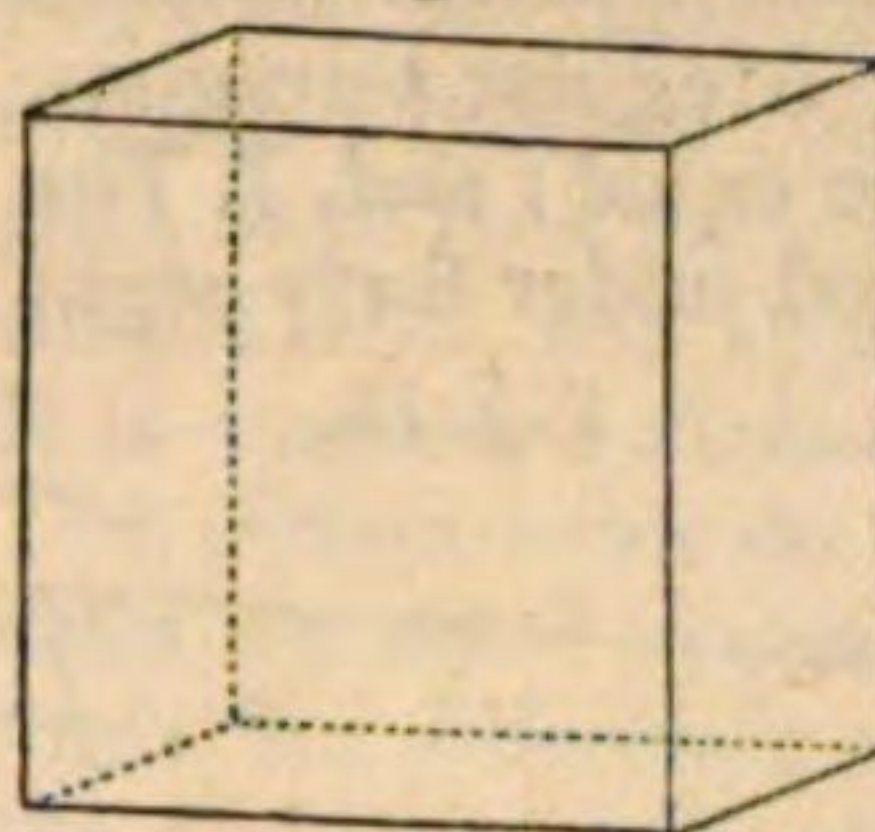


Fig. 12.

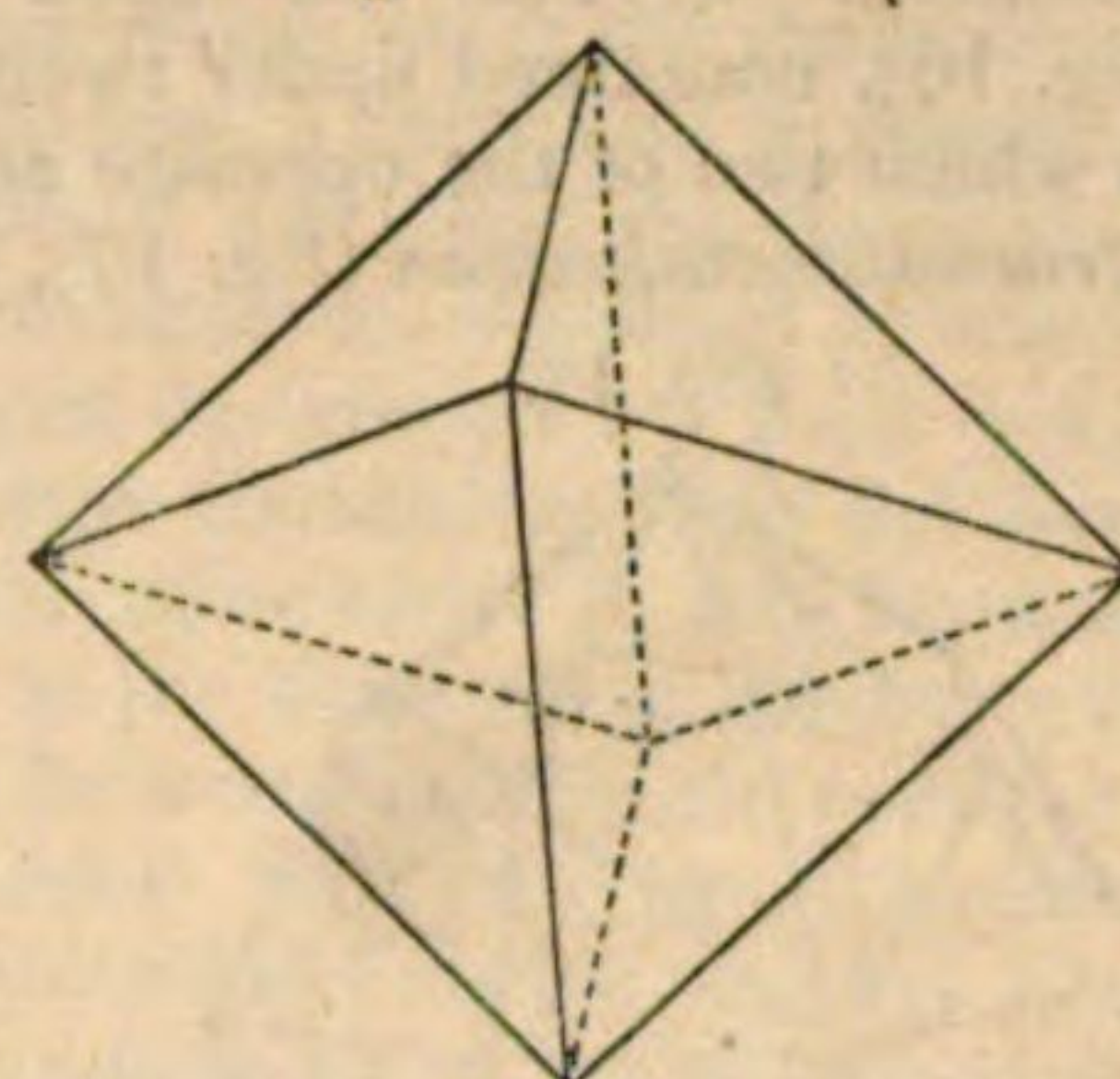


fig. 11. There are, in connection with the hexahedron, a great number of other forms, remarkable for their properties, differing, however, from each other more by their general aspect than by their dimensions. The complete assemblage of those forms is obtained in the following way. Bring first the hexahedron in an upright position, so as to bring one of its corners uppermost, and the opposite perpendicularly below it, by which means the rhomboidal axis, passing the two corners, becomes vertical; then consider the possible situations of a moveable plane, tangent to the hexahedron in the uppermost point of the said rhomboidal axis. The different situations the plane can effect are seven in number; but in one of them it becomes parallel to the face of the hexahedron itself. Every one of these situations gives rise to a peculiar form; hence there will exist as many forms as the moveable plane can assume different situations, and no more. The forms thus obtained agree

Fig. 13.

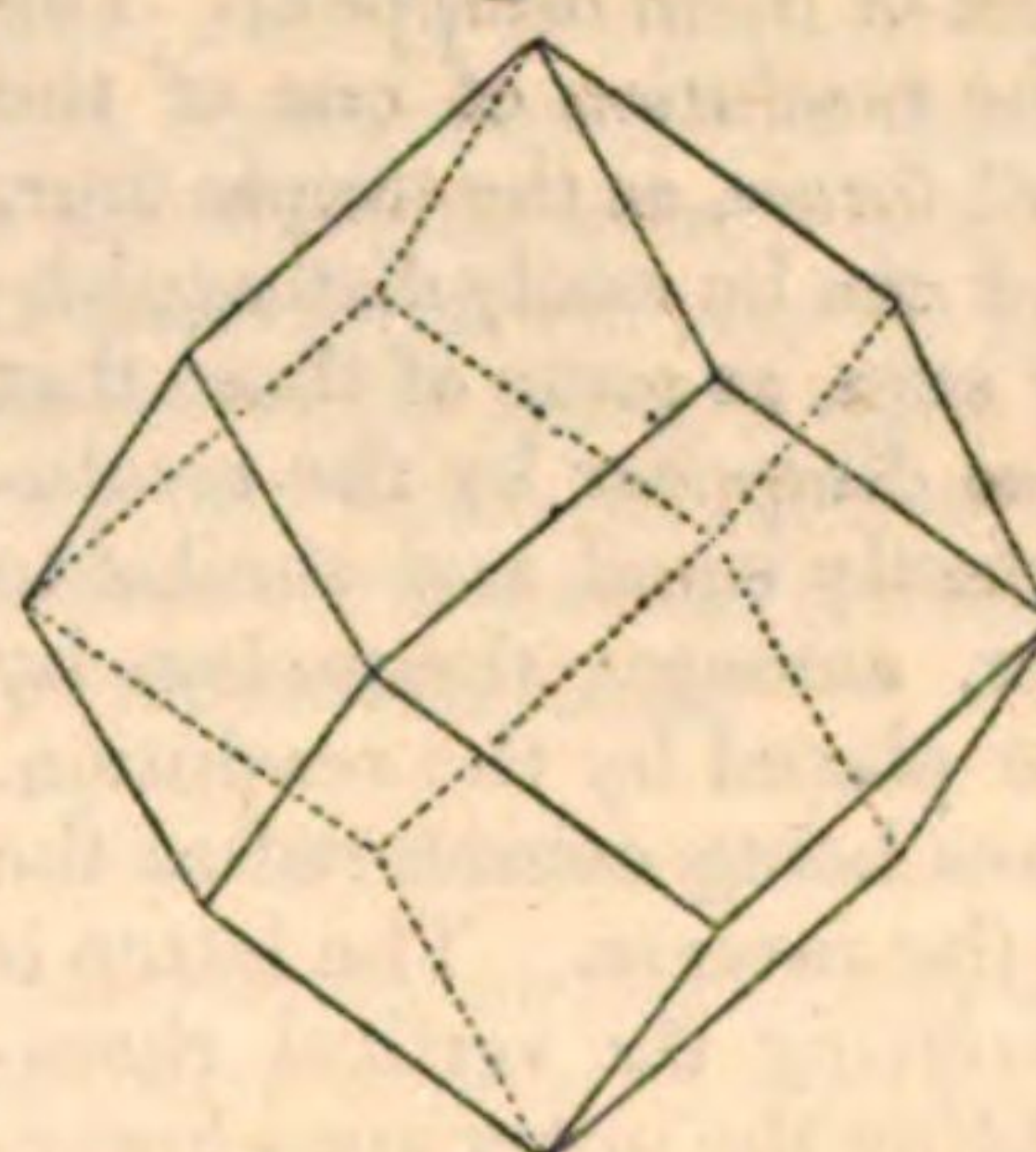
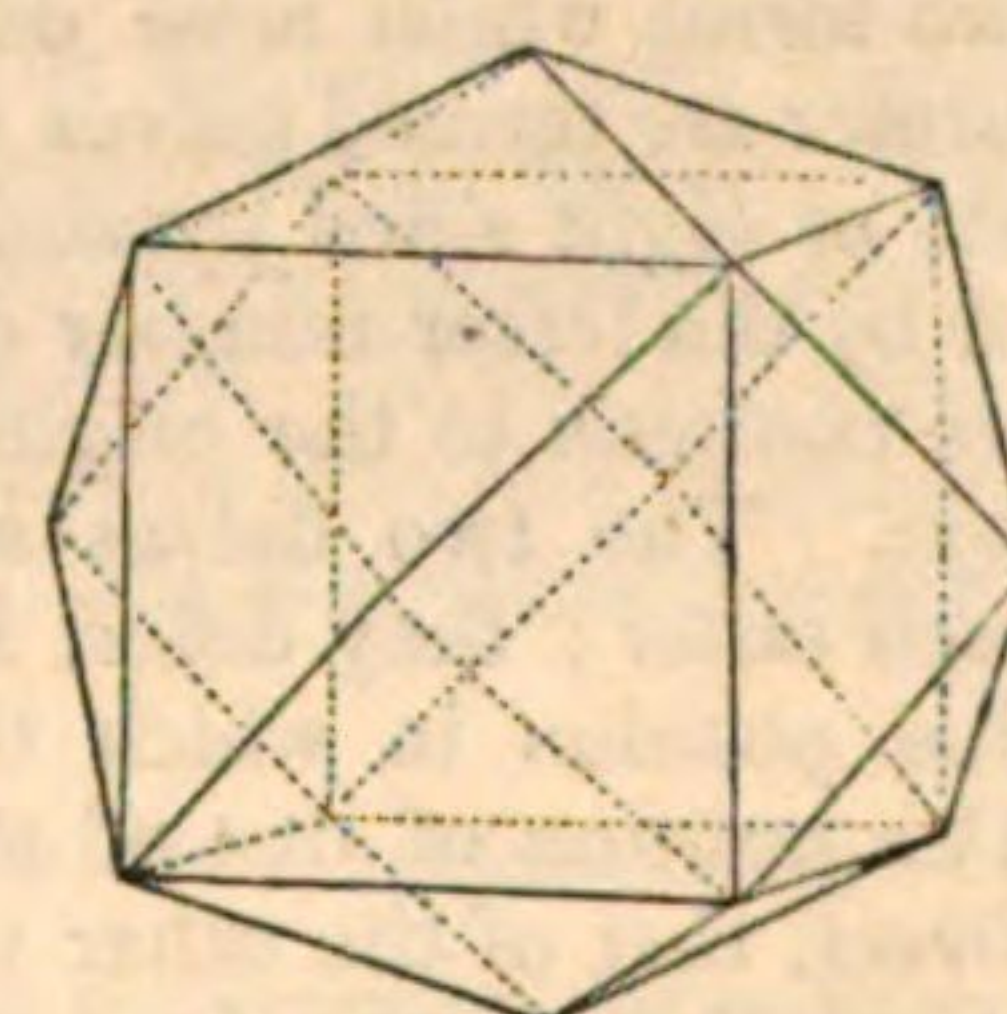


Fig. 14.



in several of their properties, particularly in respect of the kind, number, and situation of their axis, and are as fol-

Fig. 15.

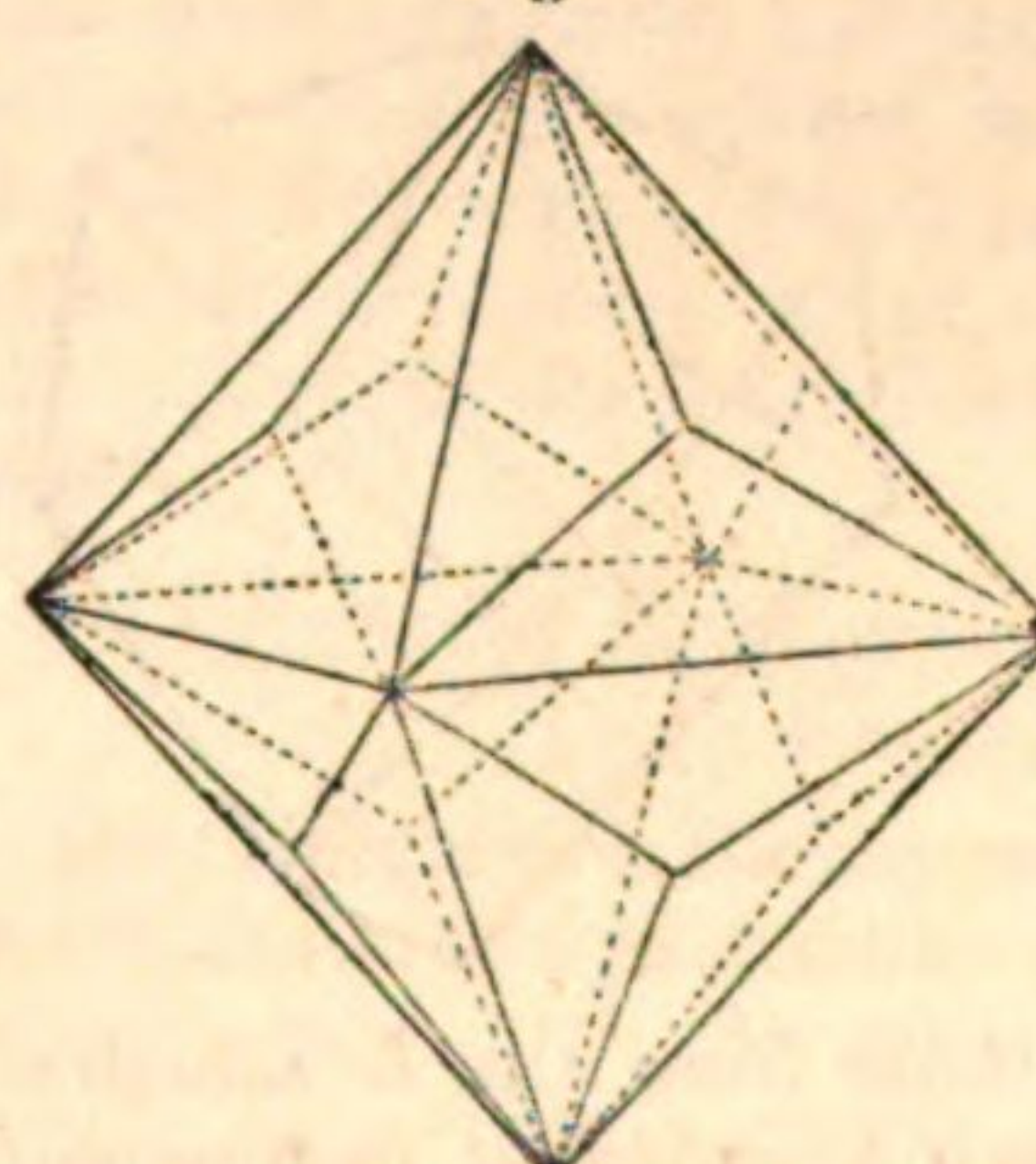
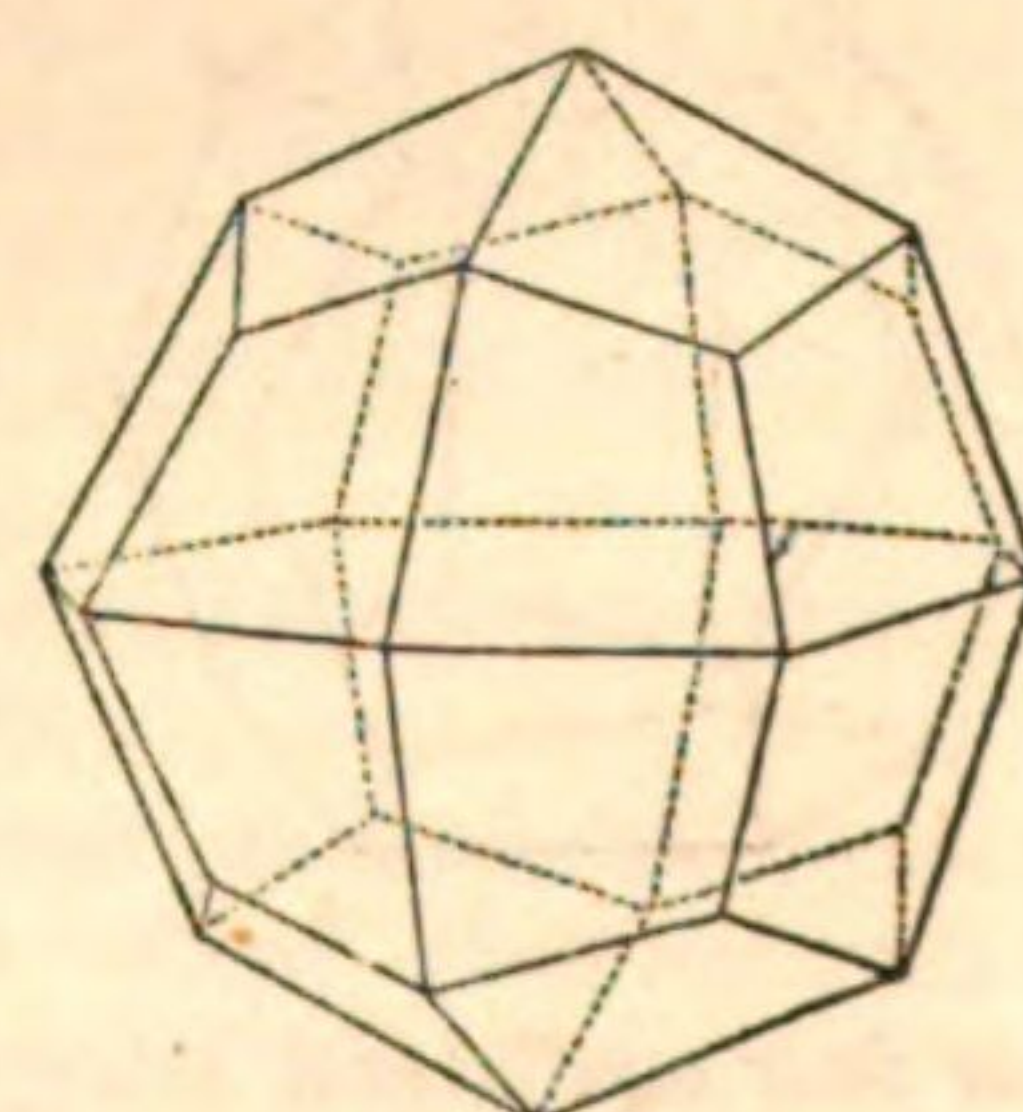


Fig. 16.



lows:—1. The *hexahedron*, contained under six squares. 2. The *octahedron*, fig. 12, contained under eight equila-

Q

Mineralogy. teral triangles. 3. The *one-edged tetragonal dodecahedron*, fig. 13, contained under twelve rhombs. 4. The *hexahedral trigonal-icositetrahedron* (fig. 14), contained under twenty-four isosceles triangles, its prominent form being that of the hexahedron. 5. The *octahedral trigonal-icositetrahedron* (fig. 15), contained under twenty-four isosceles triangles, its prominent form being that of the octahedron. 6. The *two-edged tetragonal-icositetrahedron* (fig. 16), contained under twenty-four irregular tetragons, in which two of the opposite angles are equal; and, 7. The *tetracontaoctahedron* (fig. 17), contained under forty-eight

Fig. 17.

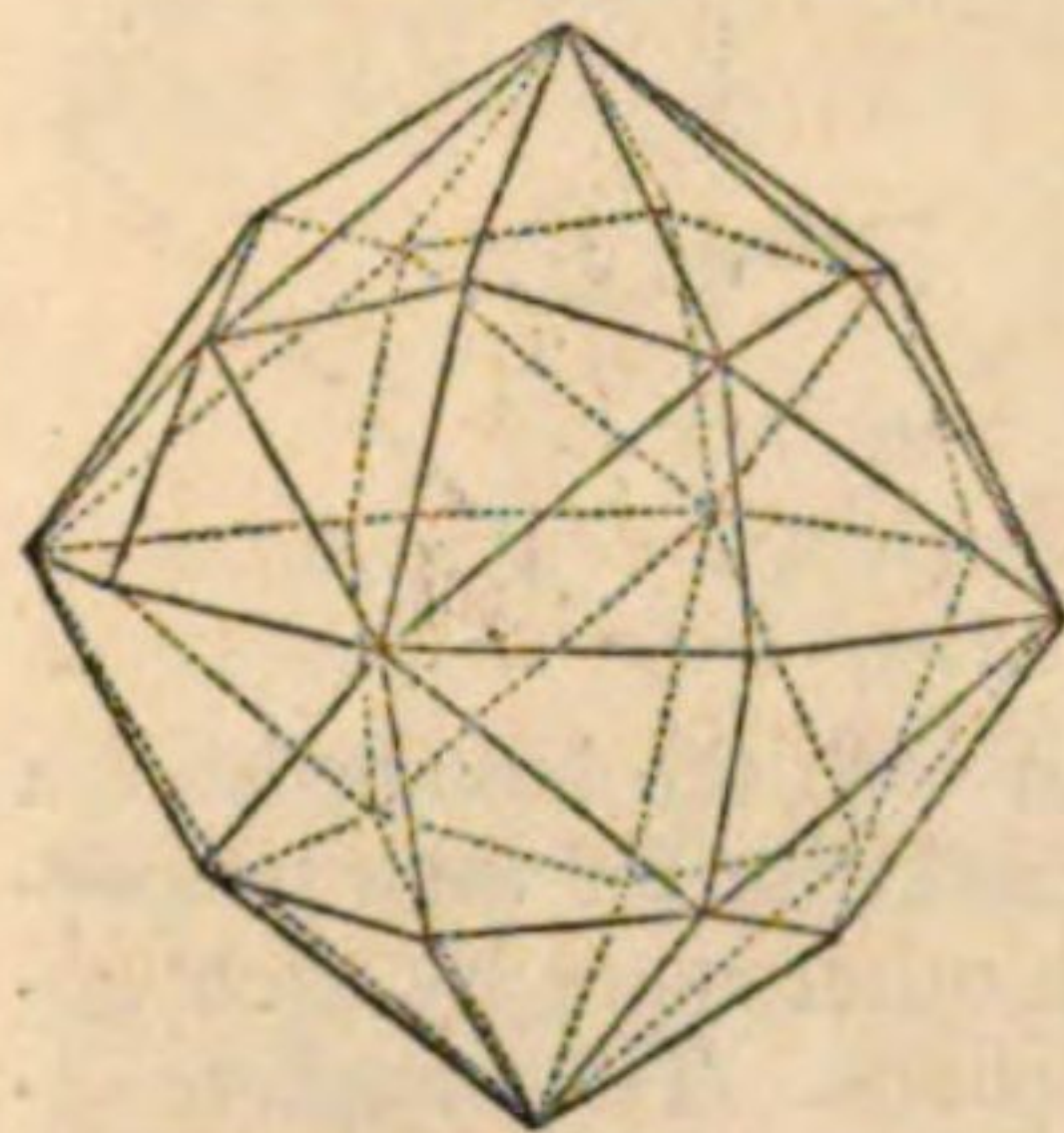
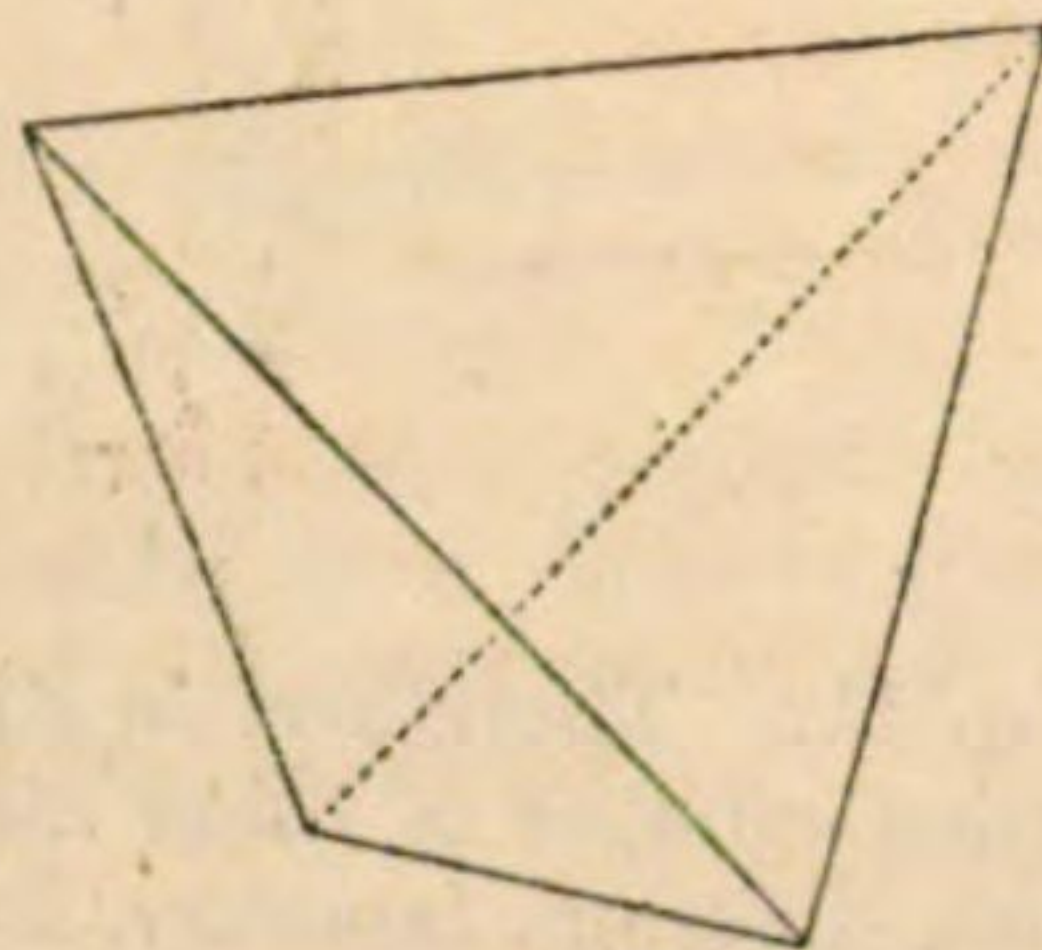


Fig. 18.



scalene triangles. The dimensions of the three first of these forms are constant, a property not to be met with in the others, of which, therefore, several varieties may be found differing from each other by their angles.

57. Resolution of some of those Forms into Halves.

This assemblage, though it is complete, seems not to contain all the forms in connection with the hexahedron, as they are produced by nature, such as, for instance, the tetrahedron, the pentagonal dodecahedrons, &c. Nevertheless it contains them, for they arise from a particular resolution of some of those mentioned in § 56. This resolution is effected by enlarging half of the number of planes to be met with in the form to be resolved, according to certain rules, and by making the rest of them disappear. The two forms which arise out of the resolution of one of the former are termed halves (not half forms, as the simple four, six, or eight sided pyramids), and can be easily distinguished by the lesser number of their axes, as some of those that are common to the original forms disappear by the resolution. The two halves are perfectly equal and similar to each other; they differ, however, amongst themselves by that position in which they are placed by the resolution. The position of one of the halves being considered as the *direct*, that of the other will be the *inverse*. The latter is changed into the former by inverting the vertical rhomboidal axis of the form, so as to bring the upper apex lowermost, and *vice versa*. Thus, the halves produced from octahedron are the two *tetrahedrons* (fig. 18), contained un-

Fig. 19.

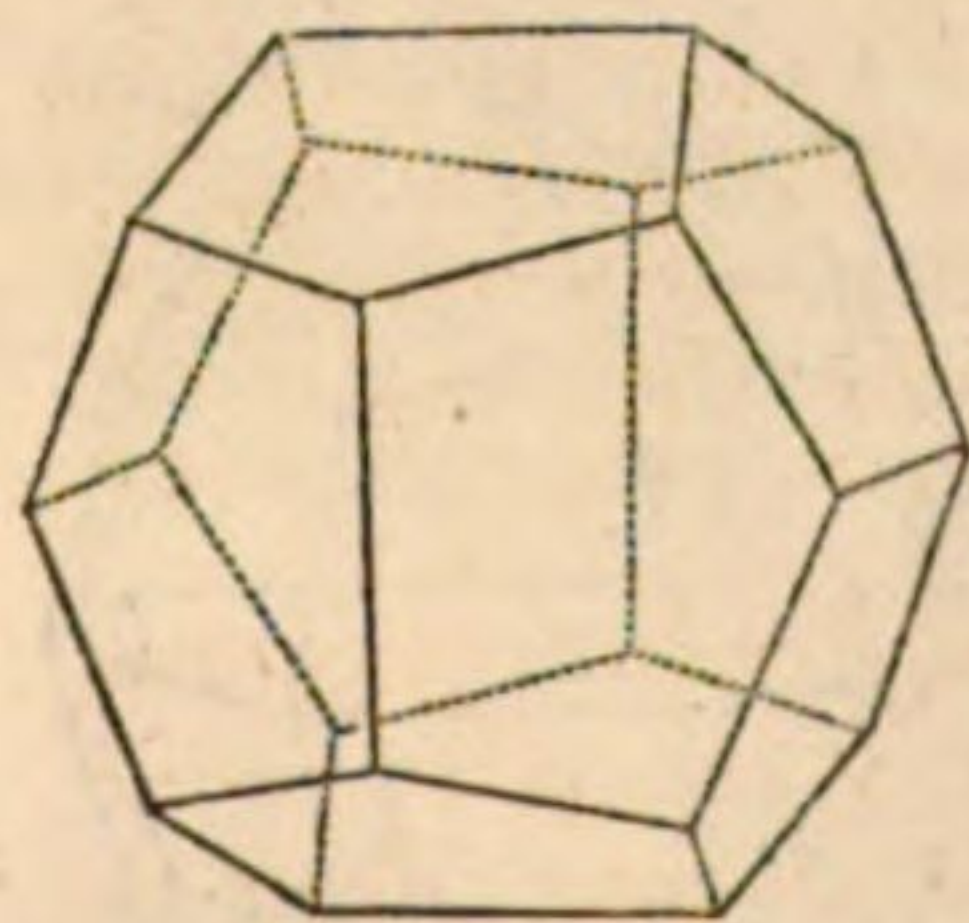
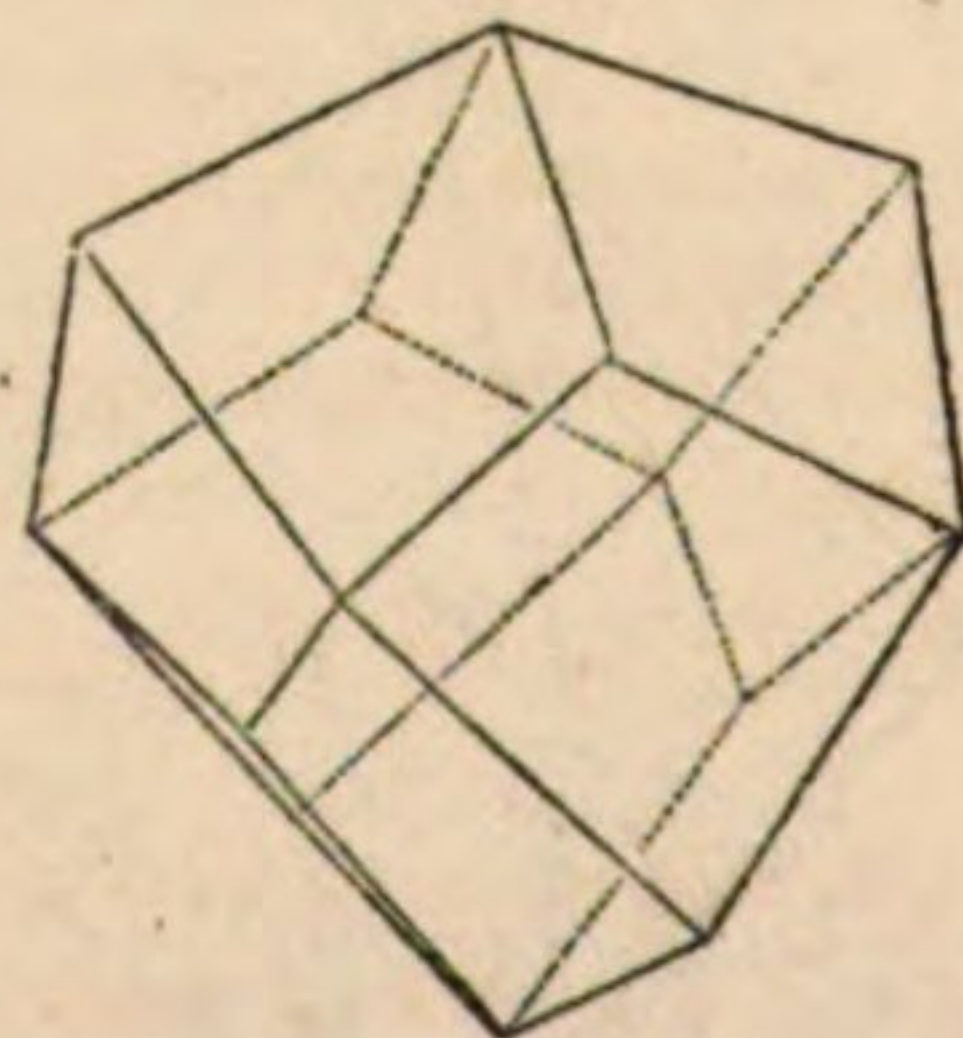


Fig. 20.



der four equilateral triangles; those from the hexahedral trigonal-icositetrahedron, the two *hexahedral pentagonal dodecahedrons* (fig. 19), contained under twelve irregular pentagons, which have two pairs of equal angles; those from the octahedral trigonal-icositetrahedron, the *two-edged*

Mineralogy. *tetragonal dodecahedrons* (fig. 20), contained under twelve tetragonal faces, in which there is only one pair of equal angles; those from the two-edged tetragonal-icositetrahedron, the two *trigonal dodecahedrons* (fig. 21), contained under twelve isosceles triangles; and lastly, the halves of

Fig. 21.

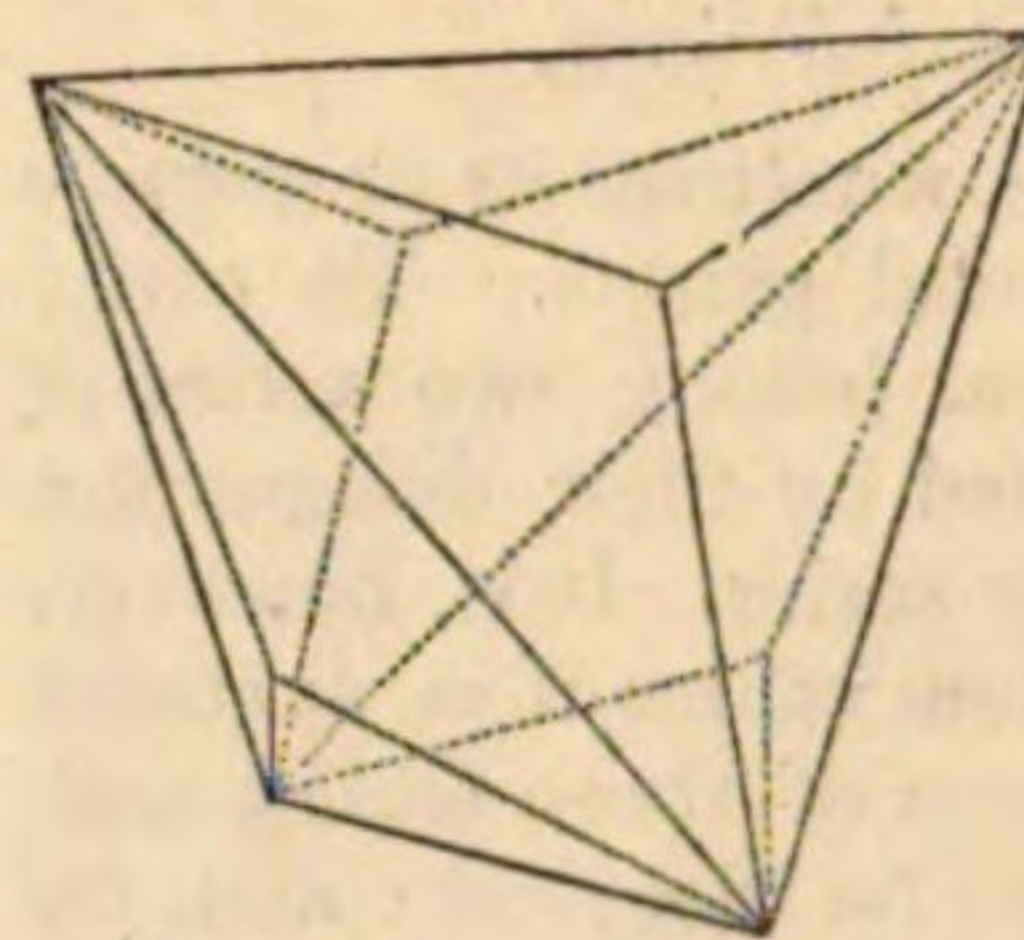
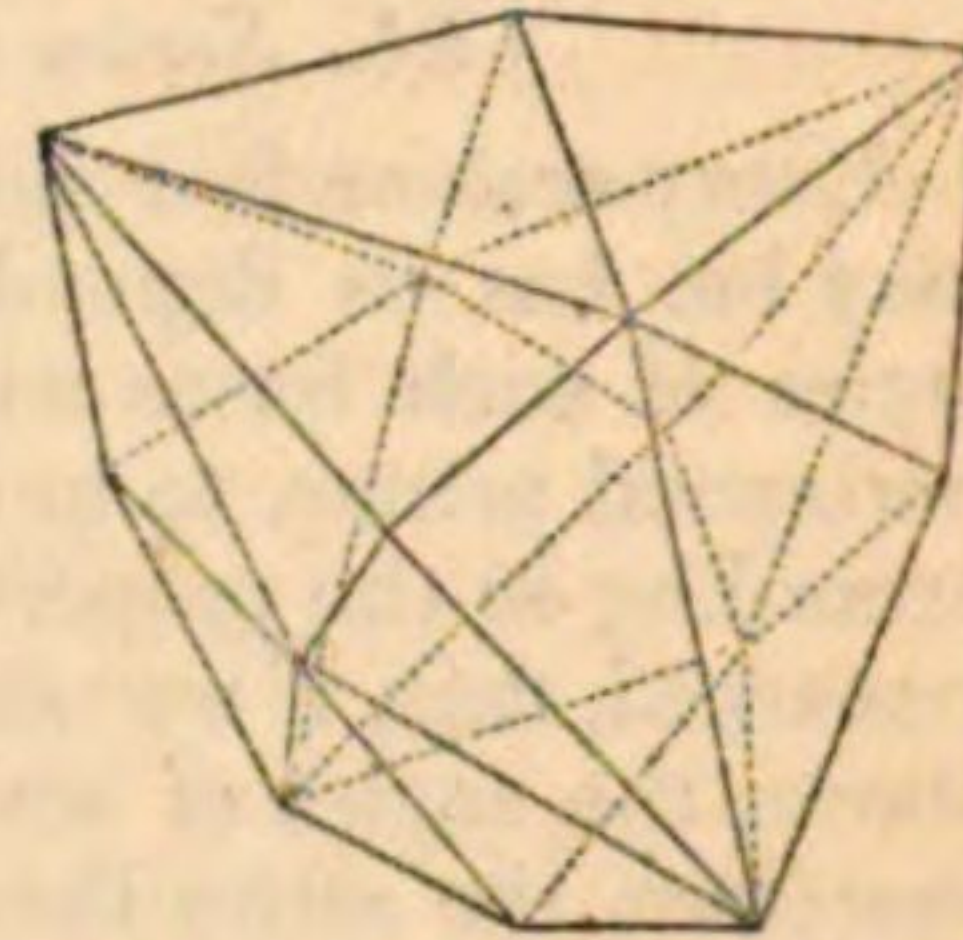


Fig. 22.



the tetracontaoctahedron, viz. *a*, the *tetrahedral trigonal-*

Fig. 23.

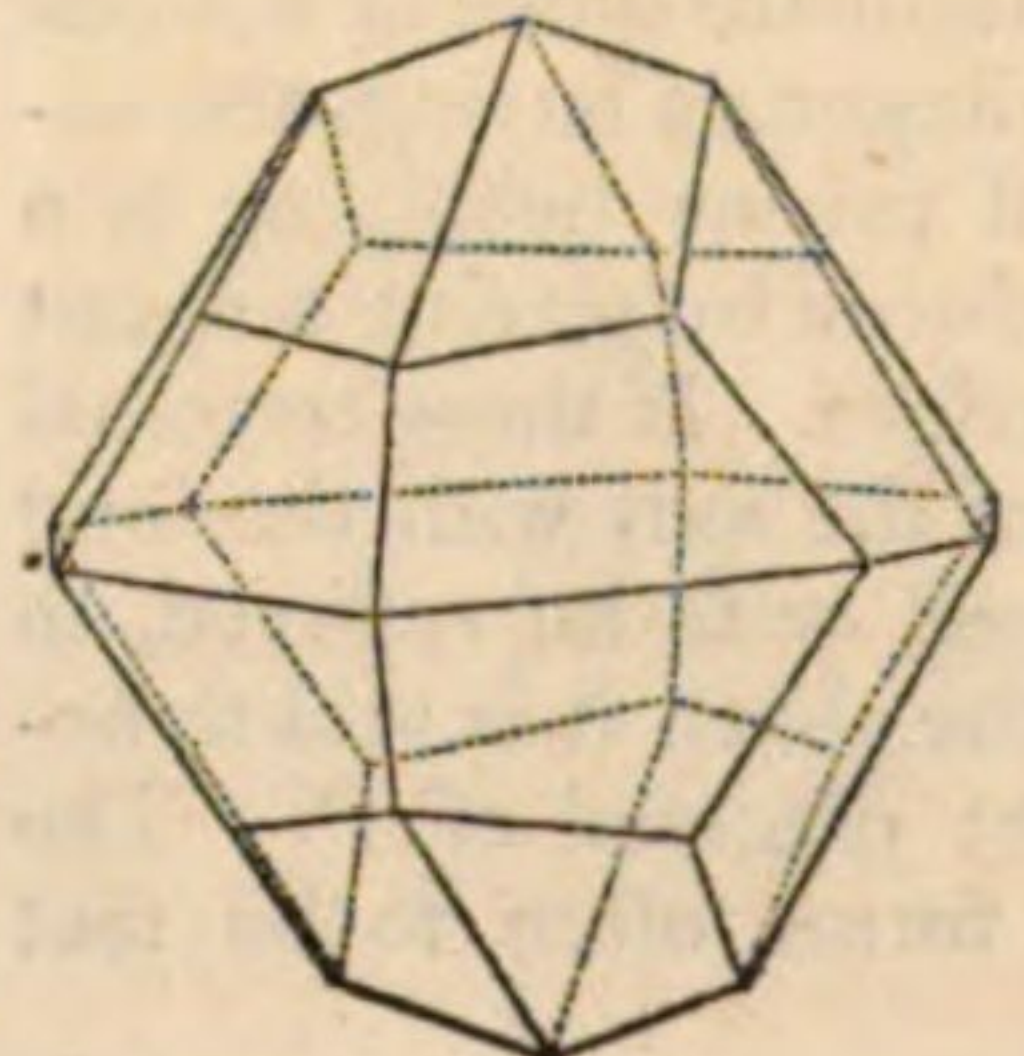
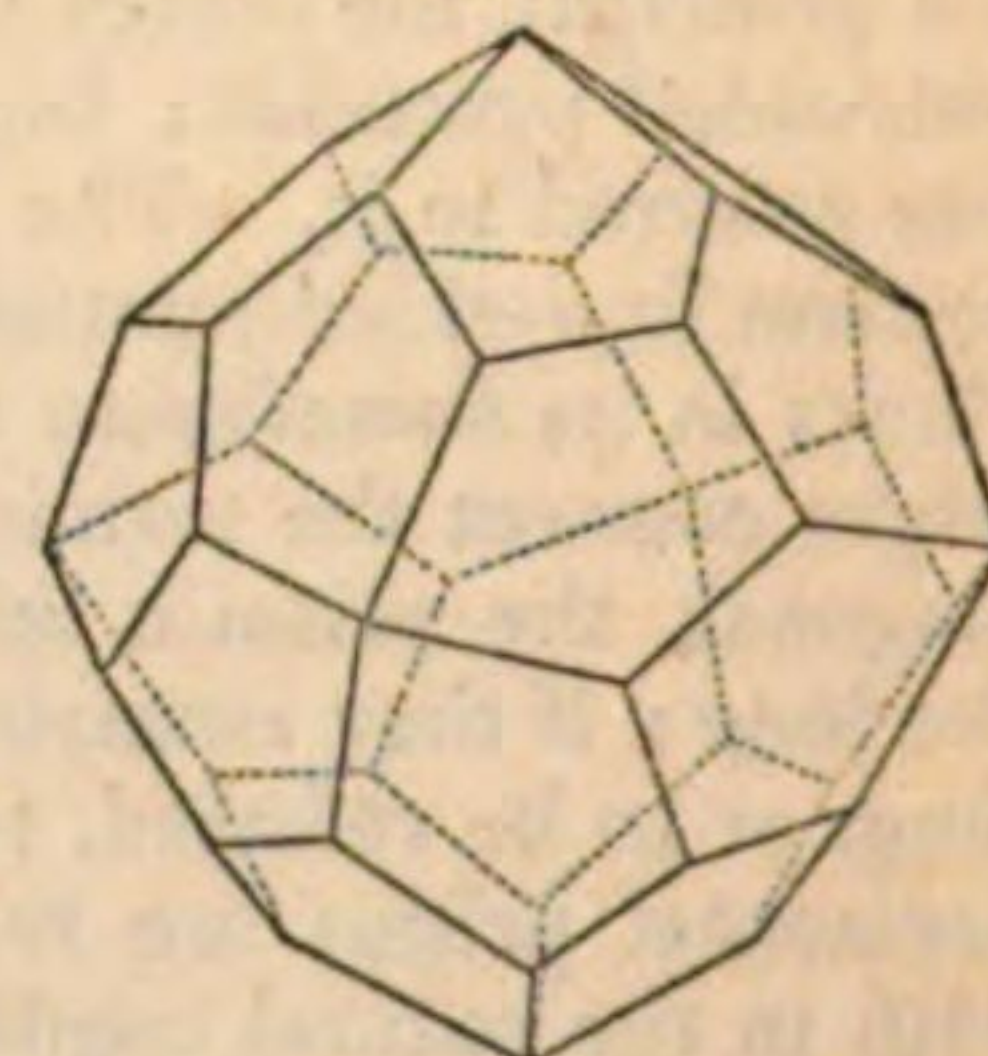
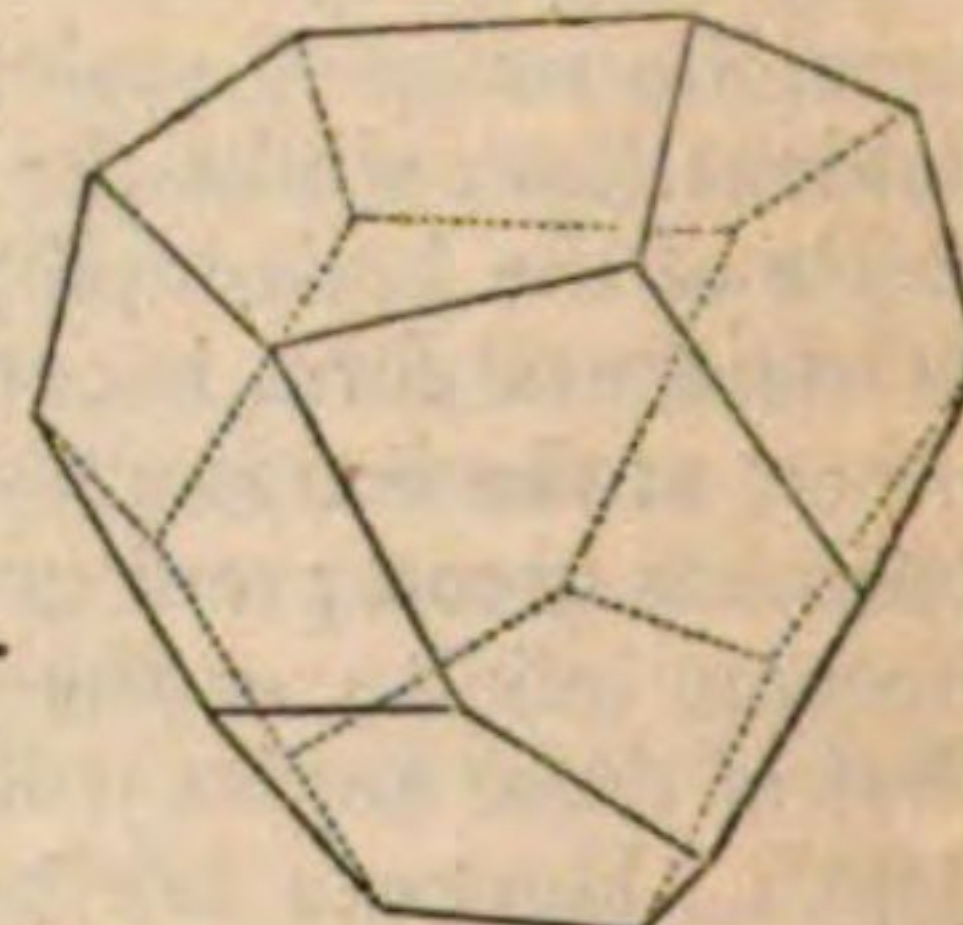


Fig. 24.



icositetrahedrons (fig. 22), contained under twenty-four scalene triangles; *b*, the *three-edged tetragonal-icositetrahedrons* (fig. 23), contained under twenty-four irregular tetragonal faces, in which there are not two equal angles; and *c*, the *pentagonal-icositetrahedrons* (fig. 24), contained under twenty-four irregular pentagons, whose angles are all different.

Fig. 25.



58. Resolution of some of the Halves into Fourths.

The three last, or those halves which are obtained from the tetracontaoctahedron, allow of a further dissolution into halves of the halves, or into *fourths*. These are the *tetrahedral pentagonal-dodecahedrons* (fig. 25), contained under twelve irregular pentagons, in which there are not two equal angles. The difference between *right* and *left*, to be met with in this form, and in the pentagonal-icositetrahedron, deserves some attention. If two-fourths are combined in the same position, which they assume in the resolution, the halves are produced; and if the halves, produced by this combination, are combined likewise in their proper position, they will reproduce the original form, out of which the halves as well as the fourths have been obtained by way of resolution. Most of the original forms and their halves are already known in several varieties of minerals; some of the latter, viz. the tetrahedral pentagonal-dodecahedrons, and the pentagonal-icositetrahedrons, have not yet been found.

59. System of Crystallization and Series of Crystallization.

If only the *kind* of the fundamental form has been considered, the assemblage of the forms derived from it is called a *system of crystallization*; but if also notice has been taken of its dimensions, the assemblage of the derived forms receives the denomination of a *series of crystallization*. These two notions are of the same kind, and differ

Mineralogy. only by the number of objects they contain, the latter being a particular determination of the former; and both refer not so much to the mere aggregation of forms, as to the relations prevailing amongst them.

60. Denomination of the Systems of Crystallization.

The systems of crystallization, agreeing in number with the fundamental forms, of which there are four, receive their names according to those fundamental forms. That which has been derived from the rhomboid is called the *rhomboidal system*, because its forms agree with the rhomboid in their general properties; that which has been derived from the isosceles four-sided pyramid, for the same reason, the *pyramidal system*; that which has been derived from the scalene four-sided pyramid, the *prismatic system*, on account of the great number and variety of prisms it contains; and that which has been derived from the hexahedron, the *tessular system*, in order to intimate that there occurs no other system of crystallization in nature which shares in the general properties of the hexahedron. It is evident that any form, if known, will suffice for the determination of the system to which it belongs, even though this form be a limiting one. Only the right rectangular four-sided prism is an exception, since it may be a simple form in the tessular, a double combination ($P-\infty \cdot P+\infty$) in the pyramidal, and a triple combination ($P-\infty \cdot Pr+\infty \cdot Pr+\infty$) in the prismatic system. The consideration of the mere form does not decide at all in this case. Some of the means of removing this uncertainty will be explained hereafter.

61. Determination of the series of Crystallization.

A series of crystallization is determined by any one of its members, which is no limiting form, if the dimensions of it are known. These dimensions, if they are not (like those of the hexahedron, the octahedron, &c.) constant, must be made out by direct measurement. From these the dimensions of any other member, or of the fundamental form, if it has not been measured itself, can be found, in compliance with the relations developed above. The series of crystallization proves of great importance for the determination of the natural history species in the mineral kingdom. It is also an external character of the utmost value in the character of the species. This character requires, therefore, the dimensions of a member of the series to be stated, of which the most eligible is the fundamental form. The limits do not determine the series of crystallization, since, in the rhomboidal and in the pyramidal system, they are common to all; in the prismatic, at least to those series which possess a similar transverse section. Hence the obtaining the limiting forms is not sufficient for the character of the natural history species.

62. General Laws of Combination.

The second advantage flowing from the above inquiries, consists in the accurate understanding of the qualities of combinations, and of the development of their most general laws. The first of these laws stands thus:—*The forms which nature combines must belong to one series of crystallization.* The second, *The combination must be effected in that position of the several simple forms it contains, which the derivation assigns to them.* Upon these two laws depends the symmetry of the combinations, which, therefore, is not the *fundamental law of crystallization*.

63. Rhomboidal and Dirhomboidal Combinations.

An accurate investigation of the combinations is one of the most interesting parts of crystallography. Without entering into minute details, some of their relations may be shortly mentioned, as they convey general ideas of the con-

Mineralogy. nection between different forms, and as they are, therefore, of consequence in the system of arrangement and discrimination to be explained in this article.

Combinations of the rhomboidal system, produced by simple forms in such a manner that they appear in the combination with the full number of their faces, and in their proper position, are termed *rhomboidal combinations*. Such are the most common combinations in the rhomboidal system. Suppose, on the contrary, a rhomboid to combine with itself in a turned position, it will affect the shape of a simple form, and appear as an isosceles six-sided pyramid. It is termed a *dirhomboid*, and designated by $2(R+n)$. The dirhomboids do not arrange themselves with the isosceles six-sided pyramids in the same series (§ 29), because there is a difference existing in the situation of the bases in the one and in the other, as becomes evident in considering the derivation. In a similar way, two equal scalene six-sided pyramids being combined in a turned position, produce a scalene twelve-sided pyramid, which has as little right as the dirhomboid to be ranked with the simple forms, although its faces are all equal and similar to each other. Combinations produced by, or containing forms of this kind, are termed *dirhomboidal combinations*.

64. Hemi-rhomboidal and Hemi-dirhomboidal Combinations.

It sometimes happens in the rhomboidal system, that the forms enter only with half the number of their faces into a combination. If these combinations contain simple forms, they are said to be *hemi-rhomboidal*; if they contain any of the above-mentioned compound forms under this restriction, they are said to be *hemi-dirhomboidal*. A further distinction is to be made among such combinations, in as much as the faces contiguous to one apex are either parallel, or inclined to those of the other. The hemi-rhomboidal, or hemi-dirhomboidal, are said, in the first case, to be *of parallel*, in the other to be *of inclined faces*. An example will put the importance of this difference in its full light: enlarge in a scalene six-sided pyramid the alternating faces contiguous to one apex, and, at the same time, those of the opposite apex, which are *parallel* to the former, the resultant form will take the appearance of a rhomboid, without in reality being a form of this kind. If, on the contrary, the faces enlarged on the opposite apex are *inclined* to those of the former, the resultant form is contained under six trapezoidal faces.

65. Pyramidal and Hemi-pyramidal Combinations.

A relation similar to that which in the rhomboidal system has been expressed by the name of hemi-rhomboidal, is equally found in the pyramidal system, and here it constitutes the *hemi-pyramidal combinations*. The hemi-pyramidal combinations of *parallel faces* refer only to the eight-sided pyramids, which by this affect the shape of isosceles four-sided pyramids, without partaking of their other properties; those of *inclined faces* refer also to the isosceles four-sided pyramids, which yield forms analogous to the tetrahedron, whilst the result of the scalene eight-sided pyramid is a particular form, contained under eight scalene triangles.

66. Prismatic, Hemi-prismatic, and Tetarto-prismatic Combinations.

The differences already mentioned are particularly remarkable in the prismatic system. From what has been said in respect to the other systems, it becomes evident what is meant by *prismatic* and by *hemi-prismatic combinations*. The latter expression refers also to one or to several prisms, whose axes are parallel, if they enter into the combinations with only half the number of their faces. A similar relation of forms in the present system, marked by

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the expression *tetarto-prismatic*, arises, when of a scalene four-sided pyramid only the fourth part, as to the number, of the faces appear in a combination. Such a combination can also be produced by oblique angular four-sided prisms, whose axes are perpendicular to each other, when only half the number of their faces is visible. The hemi and tetarto-prismatic combinations illustrate the *oblique*, the rectangular as well as the obliquangular prisms produced by nature. These belong altogether to the prismatic system, and none of them is a simple form.

The signs of the hemi-rhomboidal, hemi-pyramidal, and hemi-prismatic, are composed of the signs of the whole forms, and of the number 2, placed below them like a divisor; instead of the latter, the signs of the tetarto-prismatic combinations contain the number 4 as divisor.

67. Tessular and Semi-tessular Combinations.

Those combinations of the tessular system, into which no halves or fourths enter, are called *tessular* combinations, and in the present place they need no further explanation. Combinations of this system, however, containing halves, are termed *semi-tessular* combinations. These allow of a further distinction into semi-tessular combinations of *parallel faces*, and into those of *inclined faces*, as is the case in the hemi-rhomboidal and hemi-pyramidal combinations. The halves peculiar to the former are those in which every face is parallel to another, as the hexahedral pentagonal-dodecahedron, the three-edged tetragonal-icositetrahedron, and the general aspect of the forms undergoes thereby no alteration. The halves peculiar to the latter have not two faces parallel to each other, as the tetrahedron, the tetrahedral trigonal-icositetrahedron, &c., and the combination itself assumes, or at least approaches to a tetrahedral aspect.

Instead of crystallographic signs, *verbal* expressions are employed, in the characteristic part of this article, when describing the forms of the tessular system; because the use of the former is in the present system subject to much greater difficulties, without affording services either so beneficial or so numerous as in the other systems.

68. Development of the Combinations.

To develop a combination is to exhibit by itself each of the simple forms which it contains (§ 4). The determination of the kind of these forms has no difficulty whatever. The homologous planes of a combination being enlarged till the rest disappear, one of the forms after the other is produced. To find out their relations, upon the knowledge of which, nevertheless, depends the demonstration of the combinations, is somewhat more circumstantial, and here the series of simple forms, produced by the derivation, shew their great utility. The following paragraph contains a general idea of the mode of proceeding followed for this purpose by crystallography, though its full explanation would require too much calculation to be given in this place.

69. Line of Combination, General Formulæ for it, and their Application.

Imagine a combination of two simple forms, whose dimensions are known, and which themselves are in such a position as is peculiar to the system of crystallization to which they belong. Suppose now two terminal edges, or two diagonals, or one terminal edge and one diagonal, that are situated in a plane which, at the same time, passes through the axis, to be prolonged, till they intersect each other above or below, in a finite or infinite distance from a horizontal plane, laid through the centre of the axis. The straight line measuring the distance between the mutual intersection of the two lengthened lines, and that in which one of the lines meets with the horizontal plane, is termed the *line of combination*. The length and situation of the line of combination are evidently dependent upon the dimensions of the combined forms; and inversely the situa-

tion of the edge of combination (§ 3.) is dependent upon the length and situation of the line of combination: for, join by a straight line the terminal point of the line of combination with one of the points of intersection between the edges and diagonals of the combined forms, amongst themselves or with each other, the prolongation of this line will equally pass through the other point of intersection, and therefore be identical with the edge of combination. Hence if two forms of a system, in a determined position, produce with a third form lines of combination equal both in length and situation, the edges of combination thus produced will be equally situated; and if the two forms enter at once into combination with the third, the edges of combination produced by the first and the third must be parallel to those between the second and the third.

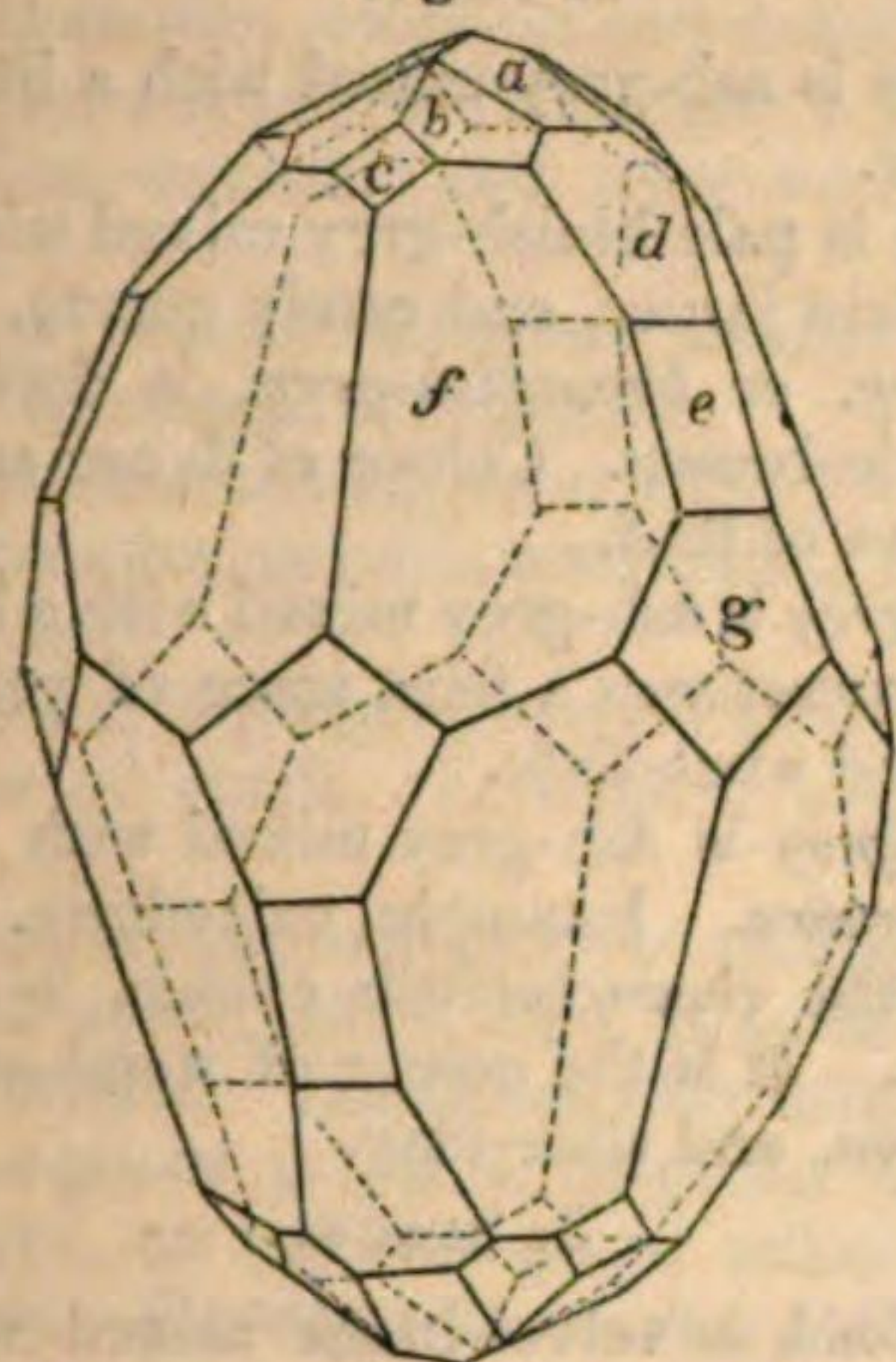
Crystallography develops general formulæ, expressing the quantity of the line of combination respecting the three first systems of crystallization (this not being required for the tessular system), in which due notice is taken of the kind of forms, their position, and the quality of the edges of combination, namely, whether the faces producing them are contiguous to one or to different apices of the simple forms. Of these formulæ, that which answers to the circumstances of a given combination between two known simple forms, is chosen and determined for that particular case, by substituting, instead of the variable quantities, *m* and *n* occurring in them, those finite numbers, which depend upon the place of the members in the series, and those factors by which the axes of the rhomboids and others have been multiplied. Thus the quantity of the line of combination, expressed either by a terminal edge, or by a diagonal, or by the axis of one or the other form contained in the combination, is found. Another formula must now be chosen, answering to a combination between *one* of these known forms, and *another unknown*, which produces with it edges of combination parallel to those in the combination of the two known forms. The formula must be determined for the case in question, by the substitution of numbers to *m* and *n*. This can only be done in respect to the known forms; *m* and *n* of the unknown remain unaltered in the expression. This expression, as is evident from the preceding, must be equal to the value of the line of combination found above. These two equal terms give an equation to be resolved for the values of *m* and *n*.

If the unknown form contains only *n* (as for instance it being a rhomboid, where *m* = 1), it is determined in the manner already mentioned. If, on the contrary, it contains *m* and *n* at once, another equation must be established in order to determine the second quantity, which is effected in the manner shewn already. Some experience in this method of developing the combinations will teach how to take advantage of certain circumstances offering themselves, by which very often it is rendered possible to argue immediately upon one of the unknown quantities *m* or *n*, or even sometimes upon both, and to determine the relations of several forms, according to such arguments, without being obliged to employ calculations.

Every simple form being thus determined as member of a series, and furnished with its crystallographic sign; the combination containing those simple forms will be designated by writing the signs for the simple forms one after the other, as some instances in the preceding, § 60, have already shewn. As to the order in which the signs succeed each other in designating a combination, there are two distinct methods, each of which may be applied. Either those forms, whose planes are perpendicular to the axis, are set down first, those whose planes are parallel to it, last; the rest following each other according to the greater or less inclination which their faces have toward the axis, as decreasing from 90° to 0°; or the forms, according to their kind, are collected into series between their limits, and then set down one after the other. The designation

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Mineralogy. $R-1 . (P-2)^5 . R . \frac{5}{4} R . R+1 . (P)^5 . R+\infty .$
 $a \quad b \quad c \quad d \quad e \quad f \quad g$
 represents fig. 26, according to the first method,
 Fig. 26.



$R-1 . R . R+1 . \frac{5}{4} R . R+\infty . (P-2)^5 . (P)^5$
 $a \quad c \quad e \quad d \quad g \quad b \quad f$
 the same, after the second method.

70. Calculation of the Angles at the Edges of Combination.

After having developed the combination, the last office of crystallography is to calculate the angles of combination, or the incidences of the faces of different forms. In many instances this angle follows at once from those of the simple forms. If this will not do, crystallography employs general formulæ for the trigonometrical functions of the edge of combination, similar to those for the line of combination, containing equally the variable quantities m and n . The development of the combinations determines these quantities, and if substituted in the said formulæ, they give the value of a trigonometrical function, commonly of the cosine of the angle, produced by two faces of different forms, meeting in the edge of combination.

II. CLEAVAGE. Foliated Fracture of Werner.

Cleavage is the property which minerals possess of splitting in certain determinate directions. The faces or planes thus obtained, which are termed the *faces of the cleavage*, are more or less smooth and shining. The forms contained under these forms are called *forms of cleavage*, or *cleavage-forms*.

The cleavage-forms represent members of the series of crystallization of those mineral species to which the mineral having the cleavage belongs. The same may be inferred of such individuals or species as possess more than one cleavage-form. Hence cleavage extends the application of crystallography in the mineral kingdom, because a mineral, although it be not crystallized, may be cleavable, and thus allow the series, at least the system of crystallization, to be made out by cleavage in most of the cases where no regular crystallizations occur.

The cleavage-forms are designated like those of crystallization. Cleavage-forms, Mohs remarks, if among the the number of those which, in the preceding pages, served as a basis to the derivation, are by preference chosen for representing the fundamental form in the species to which they belong; as in rhomboidal calc-spar, the rhomboid of $105^\circ 5'$. This rule, however, suffers an exception in the case of a rhomboid or a pyramid, which occur as cleavage-forms, being too obtuse or too acute. For this reason, in

pyramidal copper-pyrites, the fundamental form is P , though the cleavage-form is $P+1$. No cleavage-form, whose dimensions are infinite, can be employed as a fundamental form.

A few technical expressions are employed by Mohs in determining the cleavage, of which the following may be enumerated. Cleavage, in the three first systems of crystallization, which are those of variable dimensions, is said to be *axotomous*,¹ when it appears as a single plane or face perpendicular to the axis; it is said to be *paratomous*,² if it is parallel to the faces of a finite form; and *peritomous*,³ if it takes place parallel to the axis, and equally distinct in more than one direction. In the prismatic system, the expression *prismatoidal* means a single cleavage face parallel to the axis; and *diprismatic* denotes the cleavage to be parallel at the same time to the faces of a vertical, and to those of a horizontal obliquangular four-sided prism. The expression *monotomous*, referring to the three systems, is more general than any of the foregoing; it comprises the axotomous and the prismatoidal, and is applied where a single cleavage-face is met with, whose position in regard to the axes, that is to say, whether it is parallel or perpendicular to the axis, has not been determined. The perfection or distinctness of the cleavage, which is next to be considered, refers to the aspect of the faces of the cleavage, viz. whether these are more or less smooth or shining, whether they are streaked, &c. The most important object to be remarked in this respect, is the sameness of quality existing in the faces belonging to one and the same, and the diversity of faces belonging to different cleavage-forms; the latter is a particular illustrated and confirmed by the derivations of the prismatic system. The nature of the faces of the cleavage is one of the means to remove the uncertainty mentioned in § 60, on account of the right rectangular prism. Lastly, it may be remarked, that we must be careful not to confound certain faces of composition (§ 86), which sometimes likewise keep constant directions with the cleavage-forms.

III. HARDNESS

Is the resistance which solid minerals oppose, when we attempt to separate their parts.

This important character has been rendered more available by Professor Mohs, who gives the following as a useful scale of hardness:

1. *Talc*, of a white or greenish colour.
2. *Rock-salt*, a pure cleavable variety, or semitransparent *uncrystallized gypsum*, the transparent and crystallized varieties being generally too soft.
3. *Calcareous spar*, a cleavable variety.
4. *Fluor-spar*, in which the cleavage is distinct.
5. *Apatite*, the asparagus stone, or phosphate of lime, from Salzburg.
6. *Adularia felspar*, any cleavable variety.
7. *Rock-crystal*, a transparent variety.
8. *Prismatic topaz*, any simple variety.
9. *Corundum* from India, which affords smooth cleavage surfaces.
10. The *Diamond*.

If we wish, by means of this scale, to ascertain the hardness of a mineral, we first try which of the members of the scale is scratched by it. In order to save the specimens of the scale it is desirable to begin, in our determination of hardness, with the highest members of the scale, and proceed downwards, until we reach the one which is scratched. We next take a fine hard file, and draw along its surface, with the least possible force, the specimen we

¹ From $\alpha\chi\omega\varsigma$, the axis, and $\tau\epsilon\mu\omega$, I cut; cleavable in one direction.

² From $\pi\alpha\rho\alpha$, beside, and $\tau\epsilon\mu\omega$, I cut; with cleavage planes, which are parallel with the planes of the fundamental figure, or are inclined to the axis.

³ From $\pi\epsilon\gamma\acute{\iota}$, round about, and $\tau\epsilon\mu\omega$, I cut; with surrounding cleavage planes parallel to the axis.

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are examining, and also one of the minerals in the scale whose hardness is immediately above that of the mineral which has been scratched, in order to compare them together. From the resistance they offer to the file, from the noise occasioned by their passing along it, and from the quantity of powder left on its surface, their relative hardness is deduced. If the two specimens afford the same degree of noise and resistance, and same quantity of powder, their hardness is the same. When, after repeated trials, we are satisfied to which member of the scale of hardness one mineral is most nearly allied, we say its hardness (suppose it to be felspar) is equal to 6, and write after it $H = 6.0$. If the mineral do not exactly correspond with any degree of the scale, but is found to be between two of them, we say $H = 6.5$.

In our experiments we must be careful to employ specimens, each of which nearly agree in form and size, and also as much as possible in the shape of their angles. They should also be quite pure, as, if impure, their hardness cannot be determined with accuracy.

IV. SPECIFIC GRAVITY.

The specific gravity of minerals, a very important distinctive character, is determined by means of the hydrostatic balance, the hydrometer or areometer, and Adie's apparatus, a new instrument. (*Vide* Memoirs of the Wernerian Society.) These instruments, and the mode of taking specific gravities, are given under other articles in this work.

II. CHARACTERS EMPLOYED IN THE DESCRIPTION OF THE SPECIES, SUB-SPECIES, KINDS, AND VARIETIES OF MINERALS.

1. Colour.—2. Common and Particular External Forms.—3. Distinct Concretions.—4. Surface.—5. Lustre.—6. Fracture.—7. Shape of Fragments.—8. Transparency.—9. Opalescence.—10. Streak.—11. Soiling.—12. Tenacity.—13. Frangibility.—14. Flexibility.—15. Adhesion to the Tongue.—16. Unctuousity.—17. Smell.—18. Taste.

I. COLOUR.

The colours in the mineral kingdom are not so numerous as is generally imagined; and even the varieties, although often extremely beautiful, and apparently infinite in number, bear but a small proportion to the vast series that characterize the various productions of the vegetable and animal kingdoms. Werner, who bestowed great attention on this interesting and beautiful character, enumerates *eight principal colours*, viz. white, grey, black, blue, green, yellow, red, and brown. Each of these principal colours exhibits a greater or less number of varieties; the purest variety is named the *characteristic colour*, thus snow-white, the purest colour of the white series, is the characteristic colour. Colours are further divided into *non-metallic*, or those without metallic lustre, and into *metallic*, or those with metallic lustre.

I. Definitions of the different Varieties of Colours.

NON-METALLIC COLOURS.

1. WHITE.

1. *Snow-white* is the purest colour, and agrees with that of new-fallen snow. Examples of this colour occur in Carrara marble and common quartz.

2. *Reddish-white* is snow-white with a slight intermixture of red and grey. Example, heavy-spar.

3. *Yellowish-white* is snow-white with very little lemon-yellow and ash-grey. Example, chalk.

4. *Greyish-white* is snow-white mixed with a little ash-grey. Example, quartz.

5. *Greenish-white* is snow-white mixed with a very little emerald-green and ash-grey. Example, amianthus.

6. *Milk-white* is snow-white mixed with a little Berlin-blue and ash-grey. The colour of skimmed milk. Example, calcadony.

2. GREY.

1. *Bluish-grey* is ash-grey mixed with a little blue. Example, limestone.

2. *Pearl-grey* is pale bluish-grey mixed with a little red. Example, porcelain jasper, and rarely quartz.

3. *Smoke-grey*, or *brownish-grey*, is dark bluish-grey mixed with a little brown. Colour of dense smoke. Example, dark varieties of flint.

4. *Greenish-grey* is ash-grey mixed with a little emerald-green, and has sometimes a faint trace of yellow. Example, clay-slate and whet-slate.

5. *Yellowish-grey* is ash-grey mixed with lemon-yellow and a trace of brown. Example, calcadony.

6. *Ash-grey*, the characteristic colour, is a mixture of black and white. It is the colour of wood-ashes. Example, zoisite, zircon, and slate-clay.

3. BLACK.

1. *Greyish-black* is velvet-black mixed with ash-grey. Example, basalt, Lydian stone, and lucullite.

2. *Velvet-black* is the characteristic colour of this series. It is the colour of black velvet. Example, obsidian and schorl.

3. *Pitch-black*, or *brownish-black*, is velvet-black mixed with a little yellowish-brown. Example, cobalt ochre, bituminous coal, and some varieties of mica.

4. *Greenish-black*, or *raven-black*, is velvet-black mixed with a little greenish-grey. Example, hornblende.

5. *Bluish-black* is velvet-black mixed with a little blue. Is a rare colour; is well marked in the reniform cobalt ochre from Saalfeld, Thuringia, &c.

4. BLUE.

1. *Blackish-blue* is Berlin blue mixed with much black, and a trace of red. Example, dark varieties of blue copper.

2. *Azure-blue* is Berlin-blue mixed with a little red. Examples, in bright varieties of blue copper and lapis-lazuli.

3. *Violet-blue* is Berlin-blue mixed with much red, and very little black. Examples, amethyst and octahedral fluor-spar.

4. *Lavender-blue* is pale violet-blue mixed with much grey. Examples, lithomarge and porcelain jasper.

5. *Plum-blue* is Berlin-blue with more red than in violet-blue, and a small portion of brown and black. Examples, spinel and octahedral fluor-spar.

6. *Berlin-blue* is the purest or characteristic colour of the series. Examples, sapphire, rock-salt, kyanite.

7. *Smalt-blue* is Berlin-blue, with much white, and a trace of green. Examples, pale-coloured smalt, named eschel, and some varieties of gypsum.

8. *Duck-blue* is a dark blue colour, composed of blue, much green, and a little black. Examples, ceylanite, talc, and corundum.

9. *Indigo-blue* is a deep blue colour, composed of blue, with a considerable portion of black, and a little green. Example, earthy blue iron of Eckardsberg, in Thuringia.

10. *Sky-blue*, the mountain-blue of painters, is a pale blue colour, composed of blue, green, and a little white. It is the colour of a clear sky, hence its name. Examples, lenticular copper, some varieties of fluor-spar, and of blue-spar.

5. GREEN.

1. *Verdigris-green* is emerald-green mixed with much Berlin-blue and a little white. Examples, the variety of felspar named *amazon stone*, and prismatic liriconite.

2. *Celandine-green* is verdigris-green mixed with ash-grey. Examples, green earth, Siberian and Brazilian beryl.

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3. *Mountain-green* is emerald-green mixed with much blue, and a little yellowish-grey; or verdigris-green with yellowish-grey. Examples, beryl, aqua-marine topaz.

4. *Leek-green* is emerald-green with bluish-grey and a little brown. Examples, common actynolite and prase.

5. *Emerald-green* is the characteristic or pure unmixed green. Examples, emerald, and some varieties of green malachite.

6. *Apple-green* is emerald-green mixed with a little greyish-white. Example, chrysoprase.

7. *Grass-green* is emerald-green mixed with a little lemon-yellow. Examples, uranite, smaragdite, and some kinds of green malachite.

8. *Blackish-green* is pistachio-green mixed with a considerable portion of black. Examples, augite, and precious serpentine.

9. *Pistachio-green*, the sap-green of painters, is emerald-green mixed with more yellow than in grass-green, and a small portion of brown. Examples, chrysolite and epidote.

10. *Asparagus-green* is pistachio-green mixed with a little greyish-white, or emerald-green mixed with yellow and a little brown. Example, the variety of phosphate of lime named asparagus stone, from Spain and Salzburg.

11. *Olive-green* is grass-green mixed with much brown and a little grey. Examples, garnet, olivenite, pitch-stone, and olivine.

12. *Oil-green* is emerald-green mixed with yellow, brown, and grey; or pistachio-green with much yellow and light ash-grey. Is the colour of olive-oil. Examples, yellow-blende, beryl, and pitchstone.

13. *Siskin-green* is emerald-green mixed with much lemon-yellow and a little white. Examples, uran mica and some varieties of phosphate of lead.

6. YELLOW.

1. *Sulphur-yellow* is lemon-yellow mixed with much emerald-green and white. Example, native sulphur.

2. *Straw-yellow* is sulphur-yellow mixed with much greyish-white. Examples, some varieties of schorlite and carpholite.

3. *Wax-yellow* is lemon-yellow mixed with reddish-brown and a little ash-grey; or it may be considered as honey-yellow with greyish-white. Examples, opal and yellow lead-spar.

4. *Honey-yellow* is sulphur-yellow mixed with chestnut-brown. Colour of dark varieties of honey. Examples, fluor-spar and beryl.

5. *Lemon-yellow* is the pure unmixed or characteristic colour. It is the colour of the rind of ripe lemons. Example, yellow orpiment.

6. *Ochre-yellow* is lemon-yellow mixed with a considerable quantity of light chestnut-brown. Examples, yellow earth and jasper.

7. *Wine-yellow* is lemon-yellow mixed with a small portion of red and greyish-white. Examples, Saxon and Brazilian topaz, and octahedral fluor-spar.

8. *Cream-yellow*, or *Isabella-yellow*, contains more red and grey than the wine-yellow, and also a little brown. Examples, bole from Strigau and compact limestone.

9. *Orange-yellow* is lemon-yellow with carmine-red. It is the colour of the rind of the ripe orange. Examples, uran-ochre, and some varieties of molybdate of lead.

7. RED.

1. *Aurora*, or *morning-red*, is carmine-red mixed with much lemon-yellow. Example, red orpiment.

2. *Hyacinth-red* is carmine-red mixed with lemon-yellow, and a minute portion of brown; or aurora-red mixed with a minute portion of brown. Examples, hyacinth and dodecahedral garnet.

3. *Tile-red* is hyacinth-red mixed with greyish-white.

The colour of tiles or bricks. Examples, fresh burned porcelain jasper, and some varieties of foliated zeolite.

4. *Scarlet-red* is carmine-red mixed with a very little lemon-yellow. Example, light red cinnabar from Wolfstein.

5. *Blood-red* is scarlet-red mixed with a small portion of black. The colour of blood. Example, pyrope.

6. *Flesh-red* is blood-red mixed with greyish-white. Examples, felspar and heavy spar.

7. *Carmine-red* is the characteristic colour. The colour of carmine. Examples, spinel, particularly in thin splinters, also in rubellite.

8. *Cochineal-red* is carmine-red mixed with bluish-grey. Examples, cinnabar and certain garnets.

9. *Crimson-red* is carmine-red mixed with a considerable portion of blue. Examples, oriental ruby and cobalt bloom.

10. *Columbine-red* is carmine-red with more blue than the preceding variety, and, what is characteristic for this colour, a little black. Example, precious garnet.

11. *Rose-red* is cochineal-red mixed with white. Examples, red manganese and rose-quartz.

12. *Peach-blossom-red* is crimson-red mixed with white. The colour of the blossoms of the peach. Example, red cobalt-ochre.

13. *Cherry-red* is crimson-red mixed with a considerable portion of brownish-black. Examples, spinel, red antimony, and precious garnet.

14. *Brownish-red* is blood-red mixed with brown. The colour of reddle, a ferruginous clay used in drawing, and of columnar clay ironstone.

8. BROWN.

1. *Reddish-brown* is chestnut-brown mixed with a little red and yellow; or chestnut-brown with a small portion of aurora-red. Examples, brown-blende from the Hartz, and pyramidal zircon.

2. *Clove-brown* is chestnut-brown mixed with cochineal-red and a little black. It is the colour of the clove. Examples, rock-crystal and axinite.

3. *Hair-brown* is clove-brown mixed with ash-grey. Examples, wood-opal and brown iron-ore.

4. *Broccoli-brown* is chestnut-brown mixed with much blue and a small portion of green and red. Example, zircon.

5. *Chestnut-brown* is the characteristic or pure brown colour. Example, Egyptian jasper.

6. *Yellowish-brown* is chestnut-brown mixed with a considerable portion of lemon-yellow. Examples, iron-flint and jasper.

7. *Pinchbeck-brown* is yellowish-brown with metallic or semi-metallic lustre. Rather the colour of tarnished pinchbeck. Example, mica.

8. *Wood-brown* is yellowish-brown mixed with much pale ash-grey. Examples, mountain wood and bituminous wood.

9. *Liver-brown* is chestnut-brown mixed with olive-green and ash-grey. The colour of boiled liver. Example, common jasper.

10. *Blackish-brown* is chestnut-brown mixed with black. Examples, mineral pitch from Neufchatel, and moor coal.

METALLIC COLOURS.

1. WHITE.

1. *Silver-white* is yellowish-white, with metallic lustre. Examples, arsenical pyrites and native silver.

2. *Tin-white* is milk-white, with metallic lustre. Example, native antimony.

2. GREY.

1. *Lead-grey* is bluish-grey, with metallic lustre. Example, galena or lead-glance.

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2. *Steel-grey* is dark ash-grey with metallic lustre. Example, native platina.

3. BLACK.

1. *Iron-black* is greyish-black with metallic lustre. Example, black or magnetic iron-ore.

4. YELLOW.

1. *Brass-yellow* is sulphur-yellow with metallic lustre. Example, copper-pyrites.

2. *Bronze-yellow* is brass-yellow mixed with steel-grey, and a minute portion of reddish-brown. Example, iron pyrites.

3. *Gold-yellow* is lemon-yellow with metallic lustre. Example, gold-yellow native gold.

5. RED.

1. *Copper-red* is flesh-red with metallic colour. Examples, native copper and copper nickel.

II. *The Play of the Colours.*

If we look on a mineral which possesses this property, we observe, on turning it slowly, besides its common colours, many others, which are distributed in small shining points. It is beautifully seen in the diamond when cut, and also in precious opal, both in the rough state and when polished.

III. *The Changeability of the Colours.*

When the surface of a mineral, which we turn in different directions, exhibits, besides its common colours, different bright colours, that do not change so rapidly, are fewer in number, and occur in larger patches than in the play of the colour, it is said to exhibit what is called the changeability of the colours. The changeability of colour is seen only in particular directions connected with the structure of the mineral, while the play of colour is visible in all directions. Example, Labrador felspar.

IV. *Opalescence.*

Consists in a kind of reflected milky-light, which some minerals exhibit when cut *en cabachon*, or upon plain faces both natural and artificial. This appearance in catseye stone is alleged to be owing to the fibrous structure of the mineral; while in adularia and sapphire, in which it is beautifully seen, it is traced to the foliated structure.

V. *The Iridescence.*

When a mineral exhibits the colours of the prism or the rainbow, arranged in parallel, and sometimes in variously curved layers, it is said to be iridescent. This appearance is supposed in some cases to depend on fissures in the interior of the mineral, as in iridescent rock-crystal, or on the lamellary structure, as in iridescent or rainbow calcedony.

VI. *Tarnished Colours.*

A mineral is said to be tarnished when it shews on its external surface, or on that of the distinct concretions, fixed colours different from those on its interior or fresh fracture.

Tarnished colours are *simple* or *variegated*.

I. *Simple.*

- a. *Grey*,—white cobalt.
- b. *Black*,—native arsenic.
- c. *Brown*,—magnetic pyrites.
- d. *Reddish*,—native bismuth.

II. *Variegated.*

The variegated, or party-coloured, are distinguished according to the colour of their basis. Of these the following are enumerated by Werner.

- a. *Pavonine*, or *peacock-tail tarnish*. This is an as-

semblage of yellow, green, blue, red, and brown colours, on a yellow ground. The colours are nearly equal in proportion, and are never precisely distinct, but always pass more or less into one another. Example, copper-pyrites.

b. *Iridescent*, or *rainbow tarnish*. In this variety the colours are red, blue, green, and yellow, on a grey ground. It is more beautiful and brighter than the preceding. Example, specular iron-ore or iron-glance of Elba.

c. *Columbine*, or *pigeon-necked tarnish*. The colours are the same as in the preceding, with this difference, that the tints of colour are paler, and the red predominates. Example, native bismuth of Schneeberg.

d. *Tempered-steel tarnish*. The colours are very pale blue, green, and very little yellow. Example, grey cobalt.

VII. *Colour Suite.*

Where more than one colour occurs in a species, we find that the tints form characteristic groups or suites, peculiar to the species.

VIII. *Dichroism.*

Some minerals when examined by transmitted light in determinate directions, exhibit different colours. This property is called dichroism. Iolite, tourmaline, and mica exhibit this phenomenon. Iolite is blue in the direction of the axis, yellow or grey perpendicular to it; some varieties of tourmaline are nearly opaque in the direction of the axis, while they display several degrees of transparency, and different green, brown, and blue colours in the direction perpendicular to it; several varieties of mica are green in the direction of the axis, but brown perpendicular to it.

II. COMMON AND PARTICULAR EXTERNAL FORMS.

1. *Common External Shape.*

Common external shapes are those in which there are neither a determinate number of planes meeting under determinate angles, nor any resemblance to known natural or artificial bodies. As they occur more frequently than the other shapes, they are named *common external shapes*.

Six different kinds are enumerated by Werner, which are distinguished according to their relative length, breadth, and thickness, their relative magnitude, and their connections with other minerals. The kinds are *massive*, *disseminated*, *in angular pieces*, *in grains*, *in plates*, and *in membranes*.

1. *Massive* is that common external shape which is from the size of a hazel-nut to the greatest magnitude, and whose dimensions, in length, breadth, and thickness, are nearly alike. It occurs imbedded in other minerals. A very common form.

2. *Disseminated* is from the size of a hazel-nut until it is scarcely visible, and its dimensions, in length, breadth, and thickness, are nearly alike. It occurs imbedded.

3. *In angular pieces*. These are distinguished from massive, by their occurring loose and unattached. Of this external shape there are two kinds:

- a. *Sharp-cornered*, as in quartz.
- b. *Blunt-cornered*, as in common opal.

4. *In grains*. The form in grains bears the same relation to angular pieces, as disseminated does to massive. They are distinguished into *coarse*, *small*, and *fine grains*, and into *roundish*, *angular*, and *flat grains*. Examples, garnet, platina, and gold.

5. *In plates*. This form is distinguished from massive, by its dimensions in breadth and length very much exceeding that in thickness; and are generally formed in veins. Example, red silver.

6. *In membranes* or *flakes*. This shape is distinguished from the former by its thinness, as it never greatly exceeds the thickness of common paper, and the fracture cannot be seen. Examples, iron-pyrites and silver-glance.

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II. Particular External Shape.

Particular external shapes differ from the common external shapes, in bearing a resemblance to natural or artificial bodies, and in being far more characteristic and varied in their aspect. There are four different sets, entitled, *longish, roundish, flat, and cavernous*.

1. Longish Particular External Shapes.

a. Dentiform. Adheres by its thick extremity, becomes gradually thinner, incurvated, and at length terminates in a free point, so that it resembles a canine tooth, whence its name. Example, native silver.

b. Filiform. Adheres by its thicker extremity, and terminates by an almost imperceptible diminution of thickness, and is usually curved in different directions. It is thinner and longer than the dentiform. Example, native silver.

c. Capillary. When the filiform becomes longer and thinner, it forms the capillary. It is generally much entangled, and sometimes the threads are so near each other that it passes into the compact. Example, native silver.

d. Reticulated is composed of many straight threads, that cross each other under 90° , or under 120° and 60° , and thus form a reticulated shape. Example, silver-glance.

e. Dendritic. In this external shape we can observe a trunk, branches, and twigs, which are distinguished from each other by their thickness, the trunk being the thickest. Examples, native copper and native silver.

f. Coralloidal. When two or three branches, having rounded or pointed extremities, proceed from one stem, the coralloidal external shape is formed. There are usually many stems together. Example, coralloidal aragonite.

g. Stalactitic. A mineral is said to possess a stalactitic external shape, when it consists of different straight, more or less lengthened rods, which are thickest at their attachment, and become narrower at their free extremity, which is rounded or pointed. Examples, calc-sinter and calcedony.

h. Cylindrical consists of long, rounded, straight, imperforated, usually parallel rods, which are attached at both extremities, and are generally thicker at the extremities than the middle. The interstices are either empty or filled up with another mineral. Examples, galena or lead-glance.

i. Tubiform consists of long, usually single, perforated tubes, which are somewhat longitudinally knotty. Example, calc-sinter.

k. Claviform is the reverse of *stalactitic*; it is composed of club-shaped parallel rods, which adhere by their thin extremities. Example, compact black hematite.

l. Fruticose. This external shape has the appearance of cauliflower. Examples, calc-sinter and hard manganese ore.

2. Roundish Particular External Shapes.

a. Globular. Under this head are comprehended:

α. Perfect globular or spherical, as in alum-slate.

β. Imperfect globular, as in calcedony.

γ. Ovoidal or elliptical. Examples, rounded masses of quartz in puddingstone.

δ. Spheroidal. When the spherical is compressed the spheroidal is formed. Example, Egyptian jasper.

ε. Amygdaloidal. When the ovoidal is compressed in the direction of its length, the amygdaloidal is formed. Example, zeolite.

b. Botryoidal consists of large segments of small balls, which are irregularly heaped together, and thus leave considerable interstices. It resembles grapes, whence its name. Examples, hematite, hard manganese-ore, and calcedony.

c. Reniform consists of small segments of large balls, which are so closely set together that the interstices are very inconsiderable. Example, calcedony.

d. Tuberosa. This shape consists of irregular roundish or longish elevations and depressions. Example, flint.

e. Fused-like or liquiform. This consists of numerous very flat rounded elevations, which are generally depressed in the middle. Example, lead-glance.

3. Flat Particular External Shapes.

a. Specular has on one side, seldom on two opposite sides, a straight smooth shining surface. It occurs in veins. Example, galena or lead-glance.

b. In leaves. In this external shape there are thin leaves, which are either irregularly curved, or are straight, and have throughout the same thickness. It occurs frequently in native gold.

4. Cavernous Particular External Shapes.

a. Cellular. A mineral is said to be cellular when it is composed of straight or bent tables, which cross each other in such a manner as to form empty spaces or cells. Example, quartz.

b. Impressed. That is, when one mineral shews the impression of any particular or regular external shape of another mineral. It borders on the cellular shape, and is formed when a newer mineral is deposited over an older, the form of which it assumes and retains, even after the impressing mineral has been destroyed or removed.

c. Perforated consist of long vermicular cavities, which occupy but an inconsiderable portion of the mass, and terminate on the surface in small holes. When the holes become very numerous, it passes into spongiform. Example, bog iron-ore.

d. Corroded. A mineral is said to be corroded when it is traversed with numerous hardly perceptible roundish holes. Example, quartz.

e. Amorphous is composed of numerous roundish and angular parts that form inequalities, between which there are equally irregular hollows. Example, silver-glance or sulphuretted silver.

f. Vesicular. When a mineral has distributed through its interior many single, usually round, elliptical, and spheroidal, also amygdaloidal, or irregularly-shaped cavities, it is said to be vesicular. Example, wacke and lava.

III. DISTINCT CONCRETIONS.

Distinct concretions are those parts into which minerals are naturally divided, and which can be separated from one another, without breaking through the solid or fresh part of the mineral. In describing them, we have to attend to the following appearances. 1. Their shape; 2. Their surface; and, 3. Their lustre.

1. Shape of the Distinct Concretions.

They are granular, lamellar, prismatic, radiated, and fibrous.

1. *Granular distinct concretions* are those in which the length, breadth, and thickness are nearly alike. Primitive limestone or marble is composed of granular distinct concretions.

2. *Lamellar distinct concretions* are those in which the length and breadth are nearly equal, and much more considerable than the thickness. Lamellar heavy-spar affords a good example of this kind of concretion.

3. *Prismatic distinct concretions* are those in which the length is very considerable, in comparison of the thickness, thus forming irregular prisms. Examples, amethyst and prismatic heavy spar.

4. *Radiated distinct concretions* are those in which the form is thin prismatic, differing from the preceding in be-

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ing narrower, and in having the form of rays. The *radiated fracture* of Werner belongs to this division. Example, radiated iron-pyrites.

5. *Fibrous distinct concretions* are those in form of fibres. The *fibrous fracture* of Werner is included under this head. Example, actynolite.

2. Surface of the Distinct Concretions.

The surface varies considerably; in some, it is *smooth*, as in hematite; in others it is *streaked*, as in schorl, or it is uneven, as in hornblende.

3. Lustre of the Distinct Concretions.

Here the varieties of lustre are the same as already enumerated, and therefore require no particular illustration.

IV. SURFACE.

The following are the varieties of this character:—

1. *Uneven*. This, of all the kinds of external surface, presents the greatest and most irregular elevations and depressions, yet they are not so considerable as to alter the external shape. Example, surface of balls of calcedony.

2. *Granulated*. When the surface appears like shagreen, it is said to be granulated.

3. *Rough*. This kind of surface is marked with small, scarcely-visible elevations, which we can hardly discover but by the feel. It has little or no lustre. Example, rolled pieces of common quartz.

4. *Smooth*. Here there is no perceptible inequality, and the surface reflects more light than the preceding kinds of external surface. Example, fluor-spar.

5. *Streaked*. This kind of surface is marked with line-like elevations. It is either *simply streaked* or *doubly streaked*.

a. *Simply streaked* when the line-like elevations run but in one direction.

α. *Longitudinally streaked*. When the streaks are parallel with the length of the lateral planes. Example, topaz.

β. *Transversely streaked*. When the streaks are parallel with the breadth of the lateral planes. Example, rock-crystal.

γ. *Diagonally streaked*. When the streaks are parallel with the diagonal of the planes. Example, garnet.

δ. *Alternately streaked*. When transverse and longitudinal streaks occur on alternate planes. Example, cubic iron-pyrites.

b. *Doubly streaked*, when the streaks run in different directions. This is of two kinds.

α. *Plumiformly*. When the streaks run obliquely towards a principal streak, like the disposition of the parts of a feather. Example, plumose native bismuth.

β. *Reticularly*. When the streaks either cross each other in a promiscuous manner, or under right angles, forming a kind of flat net-work. Example, silver-white cobalt.

c. *Drusy*. When a crystal is coated with a number of minute crystals of the same kind as the mineral itself, the new surface is denominated drusy. Example, common iron-pyrites.

V. LUSTRE.

Here we have to consider the *intensity* and the *sort* of lustre.

1. The Intensity of the Lustre.

Of this there are five different degrees.

1. *Splendent*. A fossil is said to be splendid, when in full day-light its lustre is visible at a great distance, or when the faces produce distinct and well-defined images. Example, galena or lead-glance.

2. *Shining*. When a mineral at a distance reflects but a weak light, it is said to be shining; or when the lustre, although considerable, does not form a distinct image. Example, heavy-spar.

3. *Glistening*. This degree of lustre is only observable when the mineral is near us, and at no greater distance than arms-length; or when the surface no longer forms an image, but reflects a more feeble light than the preceding. Example, porcelain jasper.

4. *Glimmering*. If the surface of a mineral, when held near to the eye in full and clear day-light, presents a number of small, faintly-shining points, it is said to be glimmering. Example, red hematite.

5. *Dull*. When a mineral is destitute of lustre, it is said to be dull. Example, chalk.

2. The Sort of Lustre.

The following are the different kinds of lustre:—

1. *Metallic lustre*, which is always combined with opacity. It is divided into *perfect* and *imperfect*. The perfect occurs in native metals, and in all the species of the orders pyrites and glance; and the imperfect in tantalum ore, uranium-ore, and glance-coal.

2. *Adamantine*. So named from its occurring beautifully marked in the diamond. There are two varieties of this lustre, viz. the *perfect* and *metallic*: the diamond, in its rough and polished states, bright red varieties of ruby silver ore, and some varieties of blende, and carbonate of lead, afford examples of the perfect, as the dark varieties of red silver-ore, and of zinc blende, of the second.

3. *Pearly*, so named from its resemblance to the lustre observed in pearls, is divided into *common* and *metallic-like*. Mica and zeolite are examples of the first, and bron-zite of the second.

4. *Resinous* is that which a body would present if smeared with oil. Example, pitchstone and vesuvian.

5. *Vitreous* or *glassy*. The lustre of glass. Example, rock-crystal.

VI. FRACTURE.

Fracture surfaces, or planes, are those produced on breaking a mineral. The following are the principal kinds:

1. *Splintery*. When, on a nearly even fracture surface, small wedge-shaped or scaly parts are to be observed, which adhere by their thicker ends, and allow light to pass through, we say that the fracture is splintery. It sometimes passes into even. Example, quartz.

2. *Even* is that kind of fracture in which the surface is nearly even, or without inequalities. Example, Lydian-stone.

3. *Conchoidal* is composed of concave and convex roundish depressions and elevations, which are more or less regular. When regular, they are accompanied with concentric ridges, as in many shells. Examples, obsidian and rock-crystal.

4. *Uneven*. In this kind of fracture the surface is marked with numerous angular elevations. These inequalities are termed the *grain*, so that we have *coarse* and *fine-grained* uneven fractures. Example, copper-pyrites.

5. *Earthy*. When the fracture-surface shews a great number of very small elevations and depressions, which make it appear rough, it is called earthy. Example, chalk.

6. *Hackly*. When the fracture-surface consists of numerous small slightly-bent sharp inequalities, it is said to be hackly. Example, native copper.

7. *Slaty*. In this kind of fracture the mineral splits into plates or slates which are more or less perfect. Example, common roof-slate.

VII. THE SHAPE OF THE FRAGMENTS.

Fragments are those shapes which are formed when a

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Mineralogy. mineral is so forcibly struck, that masses having surrounding fracture-surfaces, are separated from it.

The fragments are either *regular* or *irregular*.

I. *Regular fragments* are enclosed in a certain number of regular planes, that meet under determinate angles. The following are the varieties of regular fragments:—

1. *Cubic*, which occur in minerals possessing a rectangular three-fold cleavage, as galena or lead-glance, and rock-salt.

2. *Rhombohedral* or *oblique angular*, which occur in minerals having a three-fold rhombohedral cleavage, as calcareous spar.

3. *Tetrahedral*, or *three-sided pyramidal* and *octahedral*, occur in minerals having a four-fold cleavage in which the folia meet under equal angles, as in fluor-spar.

4. *Dodecahedral*. Fragments of this form occur in minerals having a six-fold cleavage. Example, zinc-blende.

II. *Irregular fragments* are such as have no regular form. The following are the different varieties:—

1. *Cuneiform*, in which the breadth and thickness are much less than the length, and gradually and regularly diminish in magnitude from one end to the other. Example, radiated zeolite.

2. *Splintery*, in which the breadth and thickness are less considerable than the length, but without diminution of magnitude from one extremity to the other. Example, asbestos.

3. *Tabular*, in which the breadth and length are more considerable than the thickness. Example, clay-slate.

4. *Indeterminate angular*, in which the length, breadth, and thickness, are in general nearly alike, but the edges differ much in regard to sharpness, which gives rise to the following distinctions:—

- a. *Very sharp-edged*, as in obsidian.
- b. *Sharp-edged*, as in common quartz.
- c. *Rather sharp-edged*, as in basalt.
- d. *Rather blunt-edged*, as in pumice.
- e. *Blunt-edged*, as in gypsum.
- f. *Very blunt-edged*, as in loam.

VIII. TRANSPARENCY.

The different degrees of this character are ascertained by observing the relative quantity of light transmitted through their substance. The degrees are five.

1. When a mineral, either in thick or thin pieces, allows the rays of light to pass through it so completely, that we can clearly distinguish small objects placed behind it, as written letters, it is said to be transparent. It is either *simply transparent*, that is, when the body seen through it appears single, as in selenite; or *duplicating*, when the body seen through it appears double, as in calcareous-spar.

2. *Semi-transparent*. When objects can be discerned only through a thin piece, and then appear as if seen through a cloud, it is said to be semi-transparent. Example, calcedony.

3. *Translucent*. When the rays of light penetrate into the mineral and illuminate it, but objects placed behind it cannot be observed either through thick or thin pieces, it is said to be translucent. Example, pitch-stone.

4. *Translucent on the edges*. When the angles and edges are illuminated in the same degree as the whole mineral in the immediately preceding variety of transparency, it is said to be translucent on the edges. Example, horn-stone.

5. *Opaque*. When, even on the thinnest edges of a mineral, no light passes through, it is said to be opaque, as in chalk.

IX. OPALESCENCE.

Some minerals, when held in particular directions, reflect from single spots in their interior, a coloured shining lustre, named opalescence.

X. STREAK.

When a mineral is scratched with a hard body, as a knife or file, or is drawn across the surface of a piece of porcelain biscuit, either a powder is formed, or the scratched part acquires a higher lustre. Both these appearances are comprehended under the term streak. The lustre is increased in the streak in the malleable metals, in some glances, and in clays. Some minerals retain their colour in the streak, as the glances and haloids; while others, as many ores, all the pyrites tribe, many blendes, &c. acquire a different colour when in the streak.

XI. SOILING OR COLOURING.

When a mineral, taken between the fingers, or drawn across a surface, leaves some particles, or a trace, it is said to *soil* or *colour*.

XII. TENACITY.

By tenacity is understood the relative mobility, or the different degrees of cohesion of the particles of minerals. The degrees of tenacity are the following:—

1. *Brittle*. A mineral is said to be brittle, when, on attempting to cut it with a knife, it emits a grating noise, and the particles fly away in the form of dust, and leave a rough surface, which has in general less lustre than the fracture; it cannot therefore be cut into slices. Example, quartz.

2. *Sectile or Mild*. On cutting minerals possessing of this degree of tenacity, the particles lose their connection in a considerable degree, but this takes place without noise, and they do not fly off, but remain on the knife. Example, galena or lead-glance, and some micas.

3. *Ductile*. Minerals possessing this degree of tenacity can be cut into slices with a knife, extended under the hammer, and drawn into wire. Example, native gold.

XIII. FRANGIBILITY.

By frangibility is understood the resistance which minerals oppose, when we attempt to break them into pieces or fragments. It must not be confounded with hardness. Quartz is hard, and hornblende comparatively soft; yet the latter is much more difficultly frangible than the former.

XIV. FLEXIBILITY.

This term expresses the property possessed by some minerals, of bending without breaking. Flexible minerals are either *elastical flexible*, that is, if when bent they spring back again into their former direction; or *common flexible*, when they can be bent in different directions without breaking, but remain in the direction in which they have been bent, as molybdena, gypsum, talc, asbestos, and all malleable minerals.

XV. ADHESION TO THE TONGUE.

This character occurs only in such minerals as possess the property of absorbing moisture, which causes them to adhere to the tongue. Example, meerschaum.

XVI. TOUCH.

This character is of comparatively little importance. Some minerals feel *greasy*, others *meagre*; and in order to distinguish the different degrees of unctuousity, the following distinctions are employed:—

1. *Very greasy*, as talc and graphite.

XVII. SOUND.

Some minerals on being struck emit a *ringing* sound, as rock-crystal; others, when the finger is drawn across them, a *grating* sound, as mountain cork; natural amalgam, when pressed between the fingers, affords a *creaking* sound.

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logy.

2. *Greasy*, as steatite and fuller's earth.
3. *Rather Greasy*, as asbestos and polished serpentine.
4. *Meagre*, those that do not feel greasy, as cobalt.

XVIII. SMELL.

This character is observed under the following circumstances:—

1. *Spontaneously emitted*; in which case it is,
 - a. *Bituminous*, as mineral oil and mineral pitch.
 - b. *Faintly sulphureous*, as natural sulphur.
2. *After breathing on it*, in which a *clayey-like* smell is produced, as in hornblende and chlorite.
3. *Excited by friction*.
 - a. *Urinous*, in stinkstone.
 - b. *Sulphureous*, in iron-pyrites.
 - c. *Garlick-like*, or *arsenical*, in native arsenic and arsenic-pyrites.
 - d. *Empyreumatic*, in quartz and rock-crystal.

XIX. TASTE.

This character occurs principally in the saline class, for which it is highly characteristic.

SYSTEM OF ARRANGEMENT OF SIMPLE MINERALS.

CLASS I.

Order I.—GAS.

Genus I. HYDROGEN GAS.

1. Pure Hydrogen Gas.
2. Empyreumatic or Carburetted Hydrogen Gas.
3. Sulphuretted Hydrogen Gas.
4. Phosphuretted Hydrogen Gas.

Genus II. ATMOSPHERIC AIR.

1. Pure Atmospheric Air.

Order II.—WATER.

Genus I. ATMOSPHERIC WATER.

1. Pure Atmospheric Water.

Genus II. SEA WATER.

1. Common Sea Water.

Order III.—ACID.

Genus I. CARBONIC ACID.

1. Aeriform Carbonic Acid.

Genus II. MURIATIC ACID.

1. Aeriform Muriatic Acid.

Genus III. SULPHURIC ACID.

1. Aeriform Sulphuric Acid.
2. Liquid Sulphuric Acid.

Genus IV. BORACIC ACID.

1. Prismatic Boracic Acid.

Genus V. ARSENIC ACID.

1. Octahedral Arsenic Acid.

Order IV.—SALT.

Genus I. NATRON.

1. Hemiprismatic Natron.

Genus II. GLAUBER SALT.

1. Prismatic Glauber Salt.

Genus III. NITRE.

1. Prismatic Nitre.

Genus IV. ROCK-SALT.

1. Hexahedral Rock-Salt.

Genus V. SAL-ALMONIAC.

1. Octahedral Sal-Almoniac.

Genus VI. VITRIOL.

1. Hemiprismatic Vitriol, or Green Vitriol.
2. Tetarto-prismatic Vitriol, or Blue Vitriol.
3. Prismatic Vitriol, or White Vitriol.

Genus VII. EPSOM SALT.

1. Prismatic Epsom Salt.

Genus VIII. ALUM.

1. Octahedral Alum.

The varieties of it are,

1. *Saline*, common salt.
2. *Sweetish astringent*, natural alum and rock butter.
3. *Styptic*, blue and green vitriol.
4. *Bitter*, natural Epsom salt.
5. *Cooling*, nitre.
6. *Alkaline*, natural soda.
7. *Urinous*, natural sal-ammoniac.
8. *Acid*, sulphuric and carbonic acids.

The magnetical and electrical properties of minerals may occasionally be used in our account of species.

II. *Fluid Minerals*. In describing liquid minerals, we must attend to their colours, degree of liquidity, lustre, transparency, smell, taste, and specific gravity.

III. *Friable Minerals*. The colour, degree of coherance, lustre, soiling, feel, taste, and hardness, and specific gravity, are to be carefully noted in our description of losing aggregated or friable minerals.

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logy.

Genus IX. BORAX.

1. Prismatic Borax.

Genus X. GLAUBERITE.

1. Prismatic Glauberite.

CLASS II.

Order I.—HALOIDE.

Genus I. GYPSUM.

1. Prismatoidal Gypsum, or Common Gypsum.
2. Prismatic Gypsum, or Anhydrite.

Genus II. CRYOLITE.

1. Prismatic Cryolite.

Genus III. ALUM STONE.

1. Rhombohedral Alum Stone.

Genus IV. FLUOR.

1. Octahedral Fluor.

Genus V. APATITE.

- Rhombohedral Apatite.

Genus VI. LIMESTONE.

1. Prismatic Limestone, or Arragonite.
2. Rhombohedral Limestone.
3. Dolomite, or Macrotypous Limestone.
4. Breunnerite, or Brachytypous Limestone.
5. Ankerite or Paratomous Limestone.

Order II.—BARYTE.

Genus I. SPARRY IRON.

1. Rhombohedral Sparry Iron.

Genus II. RED MANGANESE.

1. Rhombohedral Red Manganese.

Genus III. CALAMINE.

1. Prismatic Calamine, or Silicate of Zinc.
2. Rhombohedral Calamine or Carbonate of Zinc.

Genus IV. TUNGSTEN, or SCHEELIUM.

1. Pyramidal Tungsten.

Genus V. BARYTE.

1. Peritomous Baryte, or Strontianite.
2. Di-Prismatic Baryte, or Witherite.
3. Prismatic Baryte, or Heavy-Spar.
4. Prismatoidal Baryte, or Celestine.

Genus VI. LEAD-SPAR.

1. Di-Prismatic Lead-Spar, or White and Black Lead-Spars.
2. Rhombohedral Lead-Spar, or Green and Brown Lead-Spars.
3. Hemiprismatic Lead-Spar, or Red Lead-Spar.
4. Pyramidal Lead-Spar, or Yellow Lead-Spar.
5. Prismatic Lead-Spar, or Sulphate of Lead.

Order III.—KERATE.

Genus I. CORNEOUS SILVER, or CHLORIDE OF SILVER.

1. Hexahedral Corneous Silver.

Genus II. CORNEOUS MERCURY, or MURIATE OF MERCURY.

1. Pyramidal Corneous Mercury.

Order IV.—MALACHITE.

Genus I. COPPER GREEN.

1. Uncleavable Copper Green, or Chrysocolla.

Genus II. LIRICONITE.

1. Prismatic Liriconite, or Lenticular Arseniate of Copper.
2. Hexahedral Liriconite, or Cubical Arseniate of Iron.

Genus III. OLIVENITE.

1. Prismatic Olivenite, or Prismatic Arseniate of Copper.
2. Di-Prismatic Olivenite, or Phosphate of Copper.

Genus IV. BLUE MALACHITE, or BLUE COPPER.

1. Prismatic Blue Malachite.
- * *Velvet Blue Copper.*

Genus V. EMERALD MALACHITE.

1. Rhombohedral Emerald Malachite or Diopside.

Genus VI. GREEN MALACHITE.

1. Prismatic Green Malachite, or Hydrous Phosphate of Copper.
2. Hemiprismatic Green Malachite, or Common Malachite.
3. Prismatic Green Malachite, or Muriate of Copper.

Order V.—MICA.

Genus I. COPPER-MICA.

1. Rhombohedral Copper-Mica, or Micaceous Arseniate of Copper.

Genus II. URAN-MICA, or URANITE.

1. Pyramidal Uran-Mica.
- * *Uran-Ochre.*

Genus III. COBALT-MICA, or RED COBALT.

1. Prismatic Red Cobalt.
- * *COBALT-OGRE.*
1. Black Cobalt-Ochre.
2. Brown Cobalt-Ochre.
3. Yellow Cobalt-Ochre.

Genus IV. ANTIMONY-MICA, or WHITE ANTIMONY.

1. Prismatic White Antimony.
- * *Antimony Ochre.*

Genus V. BLUE IRON, or IRON-MICA.

1. Prismatic Blue Iron.

Genus VI. GRAPHITE.

1. Rhombohedral Graphite.

Genus VII. TALC-MICA.

1. Prismatic Talc-Mica, or Talc.
1. *Native Magnesia, or Hydrate of Magnesia.* 2. *Ophite, or Precious Serpentine.* 3. *Nephrite.*
4. *Steatite, or Soapstone.* 5. *Figurestone or Algalmatolite.* 6. *Magnesite.* 7. *Meerschaum.* 8. *Lithomarge.* 9. *Mountain Soap.* 10. *Bole.*
2. Rhombohedral Talc-Mica.
3. Hemiprismatic Talc-Mica, or Common Mica.

Genus VIII. PEARL-MICA.

1. Rhombohedral Pearl-Mica.

Order VI.—SPAR.

Genus I. SCHILLER-SPAR.

1. Diatomous Schiller-Spar, or Common Schiller-Spar.
2. Hemiprismatic Schiller-Spar, or Bronzite.
3. Prismatic Schiller-Spar, or Hypersthene.
4. Prismatic Schiller-Spar, or Anthophyllite.

Genus II. KYANITE.

1. Prismatic Kyanite.

Genus III. SPODUMENE.

1. Prismatic Spodumene.

Genus IV. PREHNITE.

1. Axotomous Prehnite.

Genus V. DATOLITE.

1. Prismatic Datolite.

Genus VI. ZEOLITE.

1. Trapezoidal Zeolite, or Leucite.
2. Dodecahedral Zeolite, or Lapis Lazuli.
3. Hexahedral Zeolite, or Analcime.
4. Paratomous Zeolite, or Cross-stone.
5. Rhombohedral Zeolite, or Chabasite.
6. Diatomous Zeolite, or Laumontite.
7. Prismatic Zeolite, or Mesotype.
8. Prismatic Zeolite, or Stilbite.
9. Hemiprismatic Zeolite, or Heulandite.
10. Pyramidal Zeolite, or Apophyllite.
11. Macrytopous Zeolite, or Brewsterite.

Genus VII. PETALITE.

1. Prismatic Petalite.

Genus VIII. FELSPAR.

1. Rhombohedral Felspar, or Nepheline.
2. Prismatic Felspar, Common Felspar, or Potash Felspar.
3. Tetarto-Prismatic Felspar, or Soda Felspar.
4. Polychromatic Felspar, or Lime Felspar.
5. Pyramidal Felspar, Scapolite, Meionite.

Genus IX. AUGITE.

1. Paratomous Augite, or Common Augite, &c.
2. Hemiprismatic Augite, or Hornblende, &c.
3. Prismatic Augite, or Epidote.
4. Prismatic Augite, or Wollastone.

Genus X. AZURE-SPAR.

1. Prismatic Azure-Spar, or Lazulite.
2. Prismatic Azure-Spar, or Blue Spar.

Order VII.—GEM.

Genus I. ANDALUSITE.

1. Prismatic Andalusite.

Genus II. CORUNDUM.

1. Dodecahedral Corundum, or Spinel.
2. Octahedral Corundum, or Automolite.
3. Rhombohedral Corundum, or Sapphire.
4. Prismatic Corundum, or Chrysoberyl.

Genus III. DIAMOND.

1. Octahedral Diamond.

Genus IV. TOPAZ.

1. Prismatic Topaz.

Genus V. EMERALD.

1. Prismatic Emerald, or Euclase.
2. Rhombohedral Emerald.

Genus VI. QUARTZ.

1. Prismatic Quartz, or Iolite.
2. Rhombohedral Quartz.
3. Uncleavable Quartz.
4. Fusible Quartz.

Genus VII. AXINITE.

1. Prismatic Axinite.

Genus VIII. CHRYSOLITE.

1. Prismatic Chrysolite.
2. Hemiprismatic or Chondrodite.

Genus IX. BORACITE.

1. Octahedral Boracite.

Genus X. TOURMALINE.

1. Rhombohedral Tourmaline.

Genus IX. GARNET.

1. Pyramidal Garnet, or Vesuvian.
2. Tetrahedral Garnet, or Helvine.
3. Dodecahedral Garnet.
4. Prismatic Garnet, or Grenatite.

Genus XII. ZIRCON.

1. Pyramidal Zircon.

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Genus XIII. GADOLINITE.
1. Prismatic Gadolinite.

Order VIII.—ORE.

Genus I. MELANE ORE.

1. Prismatic Melan-Ore, or Gadolinite.
2. Anorthetic Melan-Ore, or Allanite.

Genus II. TITANIUM-ORE.

1. Hemiprismatic Titanium-Ore, or Sphene.
2. Octahedral Titanium-Ore, or Pyrochlor.
3. Peritinous Titanium-Ore, or Rutile.
4. Pyramidal Titanium-Ore, or Octahedrite.
5. Prismatic Titanium-Ore, or Brookite.

Genus III. ZINC-ORE.

1. Prismatic Zinc-Ore, or Red Zinc-Ore.

Genus IV. RED COPPER-ORE.

1. Octahedral Red Copper-Ore.

Genus V. TIN-ORE.

1. Pyramidal Tin-Ore.

Genus VI. WOLFRAM-ORE.

1. Prismatic Wolfram.

Genus VII. TANTALUM-ORE.

1. Prismatic Tantalum-Ore.

Genus VIII. FERGUSONITE.

1. Pyramidal Fergusonite.

Genus IX. URANIUM-ORE.

1. Uncleavable Uranium-Ore.

Genus X. CERIUM-ORE.

1. Rhombohedral Cerium-Ore.

Genus XI. CHROME-ORE.

1. Octahedral Chrome-Ore, or Chromat of Iron.

Genus XII. IRON-ORE.

1. Octahedral Iron-Ore, or Magnetic Iron-Ore.
2. Rhombohedral Iron-Ore, or Red Iron-Ore.
3. Prismatic Iron-Ore, or Brown Iron-Ore.
4. Diprismatic Iron-Ore, or Lievrite.

Genus XIII. MANGANESE-ORE.

1. Pyramidal Manganese-Ore, or Black Manganese-Ore.
2. Brachytypous Manganese-Ore, or Braunite.
3. Uncleavable Manganese-Ore, or Psilomelane.
4. Prismatic Manganese-Ore, or Grey Manganese-Ore.
5. Prismatic Manganese-Ore, or Pyrolusite.

Order IX.—NATIVE METALS.

Genus I. ARSENIC.

1. Rhombohedral.

Genus II. TELLURIUM.

1. Rhombohedral.

Genus III. ANTIMONY.

1. Rhombohedral Antimony.
2. Prismatic Antimony, or Antimonial Silver.

Genus IV. BISMUTH.

1. Octahedral Bismuth.

Genus V. MERCURY.

1. Liquid Native Mercury.
2. Dodecahedral Mercury, or Native Amalgam.

Genus VI. SILVER.

1. Hexahedral Silver.

Genus VII. GOLD.

1. Hexahedral Gold.

Genus VIII. IRIDIUM.

1. Rhombohedral

Genus IX. PALLADIUM.

1. Octahedral.

Genus X. PLATINA.

1. Hexahedral.

Genus XI. IRON.

1. Octahedral Iron.

Genus XII. COPPER.

1. Octahedral Copper.

Order X.—PYRITES.

Genus I. NICKEL PYRITES, or COPPER-NICKEL.

1. Prismatic Nickel Pyrites.

Genus II. ARSENIC PYRITES.

1. Axotomous Arsenic Pyrites.
2. Prismatic Arsenic Pyrites.

Genus III. COBALT PYRITES.

1. Hexahedral Cobalt-Pyrites, or Silver-White Cobalt.
2. Octahedral Cobalt-Pyrites, or Tin-White Cobalt.
3. Isometric Cobalt-Pyrites.
4. Eutomous Cobalt-Pyrites, or Nickeliferous Cobalt-Pyrites.

Genus IV. IRON PYRITES.

1. Hexahedral Iron-Pyrites.
2. Prismatic Iron-Pyrites.
3. Rhombohedral Iron-Pyrites, or Magnetic Pyrites.

Genus V. COPPER PYRITES.

1. Pyramidal Copper-Pyrites, or Yellow Copper-Pyrites.
2. Octahedral Copper-Pyrites, or Variegated Copper.

Order XI.—GLANCE.

Genus I. COPPER-GLANCE.

1. Tetrahedral Copper-Glance, or Grey and Black Copper.
2. Prismatic Copper-Glance.
3. Prismatic Copper-Glance, or Vitreous Copper.
4. Diprismatic Copper-Glance, or Bournonite.

Genus II. SILVER-GLANCE, or VITREOUS SILVER.

1. Hexahedral Silver-Glance.

Genus III. GALENA, or LEAD-GLANCE.

1. Hexahedral Galena, or Lead-Glance.

Genus IV. TELLURIUM-GLANCE, or BLACK TELLURIUM.

1. Pyramidal Tellurium-Glance.

Genus V. MOLYBDENA, or MOLYBDENA GLANCE.

1. Rhombohedral Molybdena.

Genus VI. BISMUTH GLANCE.

1. Prismatic Bismuth-Glance.
- * Bismuth-Ochre.

Genus VII. ANTIMONY-GLANCE.

1. Prismatic Antimony-Glance. Schifterz.
2. Prismatic Antimony-Glance, or Grey Antimony.
3. Axotomous Antimony-Glance. Jamesonite.
4. Peritinous Antimony-Glance, or Sulphuret of Silver and Antimony.

Genus VIII. MELANE GLANCE.

1. Prismatic Melane-Glance, Brittle Silver-Glance of Werner.

Order XII.—BLENDE.

Genus I. MANGANESE-BLENDE.

1. Hexahedral Manganese-Blende.

Genus II. ZINC-BLENDE, or GARNET-BLENDE.

1. Dodecahedral Zinc-Blende.

Genus III. ANTIMONY-BLENDE, or PURPLE ANTIMONY.

1. Prismatic Antimony-Blende, or Purple Antimony.

Genus IV. RUBY-BLENDE.

1. Rhombohedral Ruby-Blende, or Red Silver.
2. Hemiprismatic Ruby-Blende, or Cinnabar.

Order XIII.—SULPHUR.

Genus I. SULPHUR.

1. Prismatic Sulphur, or Yellow Orpiment.
2. Hemi-Prismatic Sulphur, or Red Orpiment.
3. Prismatic Sulphur, or Common Sulphur.

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CLASS III.

Order I.—RESIN.

Genus I. MELLILITE, or HONEY-STONE.

1. Pyramidal Mellilite, or Honey-Stone.

Genus II. MINERAL RESIN.

1. Yellow Mineral Resin, or Amber.
2. Black Mineral Resin.

Order II.—COAL.

Genus I. MINERAL COAL.

1. Bituminous Mineral-Coal.
2. Glance-Coal.

Mode of determining a Mineral, or of referring it to its place in the System.

The characters principally employed in the formation of what is called the *Specific Character* are the regular crystallizations (including cleavage); the degrees of hardness; and the specific gravity. The first character given in the *Specific Character* is the system of crystallization to which the form and cleavage of the species belongs. Then follows, together with its dimensions (if known), the fundamental form, from which all the other simple and compound forms are derived. In rhombohedrons, that edge which ends in the apex of the axis, that is to say, the terminal edge is given; for instance, in calcareous spar, $R = 105^{\circ}5'$; in isosceles four-sided pyramids, both edges, first the terminal one, and then that on the base, are mentioned; for instance, in pyramidal zircon, $P = 123^{\circ}19', 84^{\circ}20'$; and in scalene four-sided pyramids, first, both of the terminal edges, and then that at the basis, are given: thus, in prismatic topaz, $P = 141^{\circ}7', 101^{\circ}52', 90^{\circ}55'$. In this system, besides the dimension of the finite forms, those of the infinite ones, or of the limits, are mentioned, as in the last example, $P + \infty = 124^{\circ}19'$, and so on; which is very convenient, as the cases in which these can be examined occur more frequently than those in which the edges of pyramids can be measured.

After this follows the indication of the general aspect of the combinations, explained in the foregoing §§ 63–67, under the denominations of dirhomboidal, hemi-prismatic, &c. Of the former are mentioned the angles at the edges of combination, of the latter that terminal edge, which is formed by the intersection of the remaining faces of the scalene four-sided pyramid.

With respect to cleavage, the expression “cleavage, R,” for instance in rhombohedral calcareous spar, means, that this mineral has its cleavage parallel to the faces of a rhombohedron, similar to the fundamental form of the species; “cleavage $P - \infty$. $P + \infty$. [$P + \infty$]” in pyramidal garnet means that this mineral has its cleavage parallel to the faces of two rectangular prisms, and at the same time perpendicular to their axis; “cleavage $Pr + \infty$ ” in prismatic chrysolite, indicates that the cleavage of this mineral passes at the same time through the axis and the short diagonal of the prism $P + \infty$; and “cleavage $(Pr + \infty)^3 = 87^{\circ}42'$. $Pr + \infty$. $Pr + \infty$,” expresses, for instance, in paramorphous augite, that the individuals of this species can be cleaved, first parallel to the faces of an obliquangular four-sided prism, of the given dimensions; and, secondly, parallel to planes, which pass through the axis and both diagonals of the prism $P + \infty$; or, what comes to the same, parallel to the faces of a rectangular prism.

Characters mutually excluding each other.

If two or more characters, the one of which excludes the other, be co-existent in the character of an order, or of a genus, as in the genus Corundum, “Tessular, rhombohedral, prismatic,” the meaning is, that an individual belong-

ing to this genus must be either tessular, or rhombohedral, or prismatic; because only one of these three can take place at the same time. In the specific character this never happens, because all the forms must belong to one system.

Determination of a Mineral in general.

If a mineral is to be determined, first its *form* must be made out, at least so far as to know the system to which it belongs. Then *hardness* and *specific gravity* must be ascertained, and expressed in numbers. It is sufficient, however, to know the latter to one or two decimals. The specific character requires these data; and they are also of use in the characters of the genera, orders, and classes. This being done, the system may be consulted, and this will at the same time point out what other characters are wanting; so that a mere inspection of the mineral, or a very easy experiment, for instance, to try the streak upon a file, or, still better, upon a plate of biscuit porcelain, will be sufficient. Having advanced in this manner to the character of the species, it will, in some instances, be necessary, and in all cases advisable, for the sake of certainty, to have recourse to the dimensions of the forms. This is particularly necessary, if the genus to which the mineral belongs contains several species having forms of the same system, as is the case in the genus Augite. This termination of the dimensions of the forms may be effected by the common goniometer, the differences in the angles being in general so great, that they cannot easily be mistaken, even by the application of that instrument.

It will seldom be necessary to read over the whole of any character of a class, order, genus, or species, excepting that which includes the individual; one character that does not agree sufficing for exclusion. Thus even the characters of the orders, though the longest, will not be found troublesome.

The application of the method will become very easy and expeditious, by taking particular notice of some characters, which may be termed *prominent*. Such are a metallic aspect; a high degree of specific gravity (particularly if the mineral is not metallic), and a high degree of hardness. The observation of these will immediately decide whether an individual can belong to any particular class, order, genus, or species. It is understood, that if it be not thereby excluded, the other characters must next be examined, till either an excluding one be found, or, if not, the individual may be considered as belonging to that class, order, &c. with which it has been compared and found to agree.

Example.—The following example may serve as an illustration:—Let the form of an unknown mineral be a combination of a scalene eight-sided pyramid, of an isosceles four-sided pyramid, and of a rectangular four-sided prism; the cleavage parallel to the faces of two rectangular four-sided prisms, in a diagonal position to each other; form and cleavage, therefore, *pyramidal*, or belonging to the pyramidal system. Let the *hardness* be $= 6.5$; *specific gravity* $= 6.9$.

In this case, both hardness and specific gravity are prominent characters, and exclude at once the individual from the first and third, but not from the second class; with the characters of which its other properties also perfectly agree. Hence the individual belongs to the second class.

Comparing the properties of the individual mineral with the characters of the orders in the second class, hardness and specific gravity will be found too great for the order Haloïde; hardness too great for the orders Baryte and Kerate; both of them too great for the orders Malachite and Mica; and specific gravity too great for the orders Spar and Gem. But in the character of the order Ore, both hardness and specific gravity fall between the fixed limits, and cannot exclude the individual from this order. The other parts of this character are now to be taken in consideration. If the lustre of the individual be metallic, its

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colour must be black, otherwise it cannot belong to the order Ore. But the lustre is not metallic; therefore the colour of the individual is of no consequence; that is, this condition part of the character does not affect the individual, and consequently cannot determine its place. Since the lustre is not metallic, the individual must exhibit adamantine, or imperfect metallic lustre: the first will be found particularly in the fracture. The next part of the character refers to minerals of a red, yellow, brown, or black streak; and as the individual gives none of these, its streak being white, this part of the character does not come into consideration. Hardness keeps between the limits, as stated in the character of the order Ore. Should it be $= 4.5$ and less, the streak must be yellow, red, or black; but hardness is $= 6.5$, therefore the colour of the streak is indifferent. If the hardness be $= 6.5$ and more, and streak white, then the specific gravity must be $= 6.5$ and more. Now, this condition exists: hardness is $= 6.5$, and the streak is white; the specific gravity being $= 6.9$, which is greater than 6.5 . Lastly, the specific gravity keeps within the limits.

As far as respects the individual which is to be determined, all the characters in the characteristic of the order Ore may be divided into two parts. The first part contains those which refer to the individual; the second those which do not; the last afford no decisive distinctions. But with the first all the properties of the mineral agree. These properties agree consequently with the whole character of the order, as far as it is applicable to the individual, and determine it to belong to the order Ore; or, in shorter terms, to be an ore.

Beginners may also compare the characters of the remaining orders. Sometimes they find one individual belonging to two orders, in which case there must be evidently a mistake in the comparison, which would perhaps not have been discovered, had they stopt at the first order, which does not exclude it. In the present case, the want of metallic lustre excludes the individual from the orders Metal, Pyrites, and Glance; hardness from the order Blende; and both hardness and specific gravity from the order Sulphur. The individual can, therefore, be nothing else than an ore. The characters of the genera of the order Ore may next be examined.

If we consider again hardness and specific gravity as prominent, the individual will be immediately excluded from the genera Titanium-ore, Zinc-ore, and Copper-ore, but not from the genus Tin-ore. The form of the pyramidal system, and the white streak, shew that it belongs to this genus. From the genus Wolfram-ore, it is excluded by its too great hardness, and too low specific gravity. From the genera Tantalum, Uranium, Cerium, Chrome, Iron, and Manganese-ore, by hardness and specific gravity, both of them being too high; as also by its white streak, which only agrees with that genus from which the individual differs most by its hardness and specific gravity. The form also does not agree with any in these genera, consequently the individual can belong to no other than to the genus tin-ore.

This genus contains but one species. The conclusion that the individual must belong to this species might, nevertheless, be erroneous. There could exist a second species of this genus. The dimensions of the form must now be accurately considered. If these coincide with the angles given in the character, the highest degree of certainty that the individual belongs to or is pyramidal tin-ore, will be obtained.

Perfect determination supposes all the Characters to be known.

The perfect determination of an individual depends, as the above example has shewn, upon the possibility of making out correctly those three properties, viz. form, includ-

ing cleavage, hardness, and specific gravity. In botany it is the same. The characters must be observable, otherwise the determination will be impossible. In mineralogy, the method affords sometimes more; it leads to a correct determination, even if the knowledge of the form remains imperfect. But it will be an useful rule for beginners to occupy themselves at first with the determination of such individuals as present properties which can be easily and fully investigated. The rest will come of itself, when their knowledge of the mineral kingdom, and particularly of the properties of minerals, increases, and when they have by experience acquired the skill to judge properly of form and cleavage, at least, so far as is necessary for the determination of the system of crystallization, even in those cases where form and cleavage are somewhat difficult to be observed. This exercise is recommended to every naturalist who wishes to acquire a satisfactory knowledge of minerals, by means of the method we have here explained.

Immediate and Mediate Determination.

The method of determination, already illustrated by an example, is termed the *immediate* determination, because it is applied directly to the individual mineral which is to be determined, without the aid of one or several other minerals. If, on the contrary, we must employ one or several other minerals for this purpose, we determinate it *mediately*. That variety of hemiprismatic augite, which is known by the name *amianthus*, occurs in crystals so very seldom, as to withdraw their form, supposing it to be regular, from the sight, aided even by the most powerful magnifying instruments; cleavage is evidently still less observable. These crystals are flexible like fibres of flax, their hardness, therefore, cannot be estimated. Their surface has so great an extent in respect to their bulk, that they will swim in water, though endowed with a pretty considerable specific gravity, which, therefore, cannot be ascertained. Some varieties, however, may be observed, whose crystals are a little thicker, though in other respects, these varieties perfectly agree with amianthus. These varieties lose their flexibility, yet they are too frangible to be able to sustain the trial of hardness. Others are still thicker, but the dimensions of their forms cannot be ascertained on account of their minuteness. They sink in water, and scratch prismatic gypsum, but they break, if tried upon calcareous spar. By thus proceeding, we come to such varieties, as possessing a discernible form, allow the cleavage to be investigated; we find their specific gravity about three times that of the water, and their hardness between five and six. These will be immediately determinable, and be found to belong to the species of hemiprismatic augite. Chalk, rock-milk, clay-slate, and a great many other minerals not allowing of an immediate determination, are determined in the same way, and thus nothing escapes in the natural history method, which in any one of the other methods can be an object of determination.—*Vide Edinburgh Philosophical Journal*, where this system was first explained to English mineralogists, for fuller details in regard to the determination of species, and also for a series of observations on the principles of the Natural History method. Mr Haidinger's English translation of Mohs' Treatise is also particularly recommended to the attention of natural historians.

In the following account of simple minerals, we do not intend to describe all the species enumerated by authors, but to confine ourselves chiefly to those which are the most interesting.

CLASS I.

Specific gravity under 3.8. If solid, is sapid. No bituminous smell.

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Order I.—GAS.

Sp. gr. = 0.0001,—0.00014. Elastic. Not acid.

Genus I.—HYDROGEN GAS.

Evident smell. Sp. gr. = 0.0001,—0.00014.

1. *Pure Hydrogen Gas.*

Specific Character.—Hydrogenous smell. Sp. gr. = 0.00012.

Geognostic and Geographic Situations.—It rises from limestone, and also from the coal formation, not only in Europe, but in other quarters of the globe.

2. *Empyreumatic or Carburetted Hydrogen Gas.*

Specific Character.—Empyreumatic smell. Sp. gr. = 0.0008.

Geognostic and Geographic Situations.—Rises from marshes and from beds of coal (forming the *fire-damp* of miners) in different parts of Great Britain. It is also one of the aeriform substances given out by volcanoes.

3. *Sulphuretted Hydrogen Gas.*

Specific Character.—Smell of putrid eggs. Taste nauseous and bitter. Sp. gr. = 0.00135.

Geognostic and Geographic Situations.—Rises from marshes, sulphureous springs, and volcanoes. It is met with in many places in Great Britain.

4. *Phosphuretted Hydrogen Gas.*

Specific Character.—Smell of putrid fish. Sp. gr. unknown.

Geognostic and Geographic Situations.—It rises from marshy places, where organic substances are in a state of decomposition.

Genus II.—ATMOSPHERIC AIR.

Without smell or taste. Sp. gr. = 0.001,—0.0015.

1. *Pure Atmospheric Air.*

Specific Character.—Without smell or taste.

Constituent Parts.—Azotic gas 79, oxygen gas 21, = 100.

Forms the atmosphere which surrounds the earth.

Order II.—WATER.

Liquid. Tasteless, or with sensible taste and smell. Sp. gr. = 1.0,—1.0269.

Genus I.—ATMOSPHERIC WATER.

Without smell or taste.

1. *Pure Atmospheric Water.*

Specific Character.—Without smell or taste.

Constituent Parts.—Oxygen 88.94, hydrogen 11.06, = 100. *Berzelius.* The purest natural water contains small portions of foreign matter.

This is common rain, river, and spring water. Mineral waters might be introduced into this part of the system.

Genus II.—SEA WATER.

Sensible smell and taste.

1. *Common Sea Water.*

Specific Character.—Bitter nauseous taste, and disagreeable smell.

Constituent Parts.—In 10,000 parts of water of the Frith of Forth, common salt 220.01, sulphate of soda 33.16, muriate of magnesia 42.09, muriate of lime 7.84, = 303.09.

Order III.—ACID.

Sp. gr. = 0.0015,—3.7. Acid.

Genus I.—CARBONIC ACID.

Taste slightly acid. Sp. gr. = 0.0018.

1. *Aeriform Carbonic Acid.*

Specific Character.—Elastic. Taste acidulous and pungent.

Constituent Parts.—Carbon 27.4, oxygen 72.6, = 100. *Berzelius.*

Geognostic and Geographic Situations.—Occurs in marshy places and in acidulous waters, in Great Britain and other countries.

Genus II.—MURIATIC ACID.

Smell of saffron, and strong acid taste. Sp. gr. = 0.0023.

1. *Aeriform Muriatic Acid.*

Specific Character.—Expansible. Smell pungent and suffocating.

Constituent Parts.—Muriatic acid 73.31, water 24.69. *Berzelius.*

Geographic Situations.—Rises from volcanoes.

Genus III.—SULPHURIC ACID.

If gaseous, the smell is sulphureous. If liquid, the taste is strongly acid. Sp. gr. = 0.0025,—1.5.

1. *Aeriform Sulphuric Acid.*

Specific Character.—Expansible. Sp. gr. = 0.0028.

Constituent Parts.—Sulphur 50.144, oxygen 49.856, = 100. *Berzelius.*

Geognostic Situation.—Often rises in considerable quantities from volcanoes.

2. *Liquid Sulphuric Acid.*

Specific Character.—Liquid. Sp. gr. = 1.8,—1.9.

Geognostic Situation.—Occurs in volcanic districts in Italy, America, and Java.

Genus IV.—BORACIC ACID.

Solid. Sp. gr. 1.4 to 1.5.

1. *Prismatic Boracic Acid.*

Specific Character.—Prismatic. Pyramid unknown. Occurs in scaly crusts. Taste first sourish, or sub-acid, then bitter and cooling, and lastly sweetish.

Constituent Parts.—Boron 25.83, oxygen 74.17. *Berzelius.*

Geognostic and Geographic Situations.—Found on the edges of hot springs in Italy, &c.

Genus V.—ARSENIC ACID.

Solid. Sp. gr. above 3.0.

1. *Octahedral Arsenic Acid.*

Arsenic oxyde.—*Hauy.*

Specific Character.—Tessular. Cleavage octahedral. Taste sweetish-astringent. Hardness = 1.5. Sp. gr. = 3.6,—3.7.

Description.—Colour white, often inclining to yellow. Occurs in delicate capillary crystals; also massive, in crusts, stalactitic, reniform and botryoidal. Lustre vitreous, inclining to adamantine. Translucent or opaque.

Constituent Parts.—Arsenic 75.82, oxygen 24.18, = 100. *Berzelius.*

Geognostic and Geographic Situations.—Occurs in veins at Andreasberg in the Hartz.

Order IV.—SALT.

Sp. gr. = 1.2,—2.9. Solid. Not acid.

Genus I.—NATRON.

Prismatic. Taste pungent and alkaline. Hardness, = 1.0,—1.5. Sp. gr. = 1.4,—1.6.

1. *Hemiprismatic Natron*.

Hemiprismatisches Natron-Salz, *Mohs*.—Natürliches Mineral-Alkali, *Werner*.—Soudé carbonatée, *Haüy*.

Specific Character.—Hemiprismatic. Cleavage prismatic.

Description.—Its chief colours are grey, white, and yellow. Occurs in acicular crystals, in radiated and granular distinct concretions; also in loose earthy particles, and in crusts. Is more or less translucent.

Constituent Parts.—Dry carbonate of soda 32.6, sulphate of soda, 20.8, muriate of soda, 15.8, water of crystallization 31.6, = 100.0.

Geognostic and Geographic Situations.—Occurs in crusts on rocks and soils of different kinds; and also in the waters of natron lakes and springs. It is particularly abundant in the natron lakes in Egypt.

Genus II.—GLAUBER SALT.

Prismatic. Taste, first cooling, then saline and bitter. Hardness = 1.5, — 2.0. Sp. gr. 1.4, — 1.5.

1. *Prismatic Glauber Salt*.

Prismatisches Glauber Salz, *Mohs*.—Natürliches Glauber Salz, *Werner*.—Soudé sulphatée, *Haüy*.

Specific Character.—Prismatic. Pyramid unknown.

Combination hemiprismatic. $\frac{P}{2}$. Cleavage, $\bar{P}r + \infty$ perfect. Less perfect, $\bar{P}r + \infty$. (Fig. 29, 28.)

Description.—Colour white, sometimes inclining to yellow. Occurs in acicular crystals, granular concretions, stalactitic, in loose earthy particles, and in crusts. More or less translucent.

Constituent Parts.—Sulphuric acid 24.84, soda 19.39, water 55.77, = 100.

Geognostic and Geographic Situations.—Occurs on soils and rocks of different descriptions, in Scotland, England, and other countries.

Genus III.—NITRE.

Prismatic. Taste cooling and saline. Hardness = 2.0. Sp. gr. = 1.9, — 2.0.

1. *Prismatic Nitre*.

Prismatisches Nitrum-Salz, *Mohs*.—Natürlicher Salpeter, *Werner*.—Potasse nitrée, *Haüy*.

Specific Character.—Prismatic. Pyramid = $132^{\circ} 22'$; $91^{\circ} 15'$; $107^{\circ} 43'$. Cleavage, $\bar{P}r + \infty = 120^{\circ}$. More distinct, $\bar{P}r + \infty$. (Fig. 30, 29.)

Description.—Colour white, grey, and sometimes yellow. Occurs in acicular crystals, in crusts, and in fibrous concretions. More or less translucent.

Constituent Parts.—Potash 55.28, nitric acid 44.72.

Geognostic and Geographic Situations.—Occurs incrusting limestone, marl, sandstone, calc-tuff, chalk, and on soils of particular kinds. It is collected in limestone caves in Italy, in caves of various descriptions in America, and in abundance from the surface of the ground in many of the Tartarian plains.

Genus IV.—ROCK-SALT.

Tessular. Taste saline. Hardness = 2.0. Sp. gr. = 2.2, — 2.3.

1. *Hexahedral Rock-Salt*.

Hexaedrisches Steinsalz, *Mohs*.—Natürlich Kochsalz, *Werner*.

Specific Character.—Tessular. Cleavage, hexahedral.

Description.—Most frequent colours grey and white; sometimes also blue, red, yellow, and green. Occurs in

granular, fibrous, radiated, and prismatic concretions; massive, dentiform, and stalactitic. Lustre between vitreous and resinous. More or less transparent and translucent.

Constituent Parts.—Muriate of soda 98.32, sulphate of lime 0.65, muriate of magnesia 0.02, muriate of lime 0.01, undissolved matter 1.0, = 99. *Henry*.

Geognostic and Geographic Situations.—It occurs in beds, imbedded masses, and veins, associated with saliniferous clay, gypsum, limestone, sandstone, and anhydrite, in the salt formation; also in layers and crusts on soils of particular kinds, and deposited on the shores of salt lakes, and in the vicinity of salt springs. Occurs abundantly in Cheshire, and also in other parts of England.

Genus V.—SAL AMMONIAC.

Tessular. Taste pungent and urinous. Hardness = 1.5, — 2.0. Sp. gr. 1.5, — 1.6.

1. *Octahedral Sal Ammoniac*.

Octaedrisches Salmiac, *Mohs*.—Natürlicher Salmiac, *Werner*.—Ammoniaque Muriatée, *Haüy*.

Specific Character.—Tessular. Cleavage, octahedral.

Description.—Colours white, grey, yellow, and sometimes green and bluish. Occurs in granular and fibrous concretions; also in efflorescences, in crusts, stalactitic, botryoidal, tuberoso, and corroded. More or less translucent.

Constituent Parts.—Muriate of ammonia 99.4, sulphate of ammonia 0.5. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in crusts in the fissures and on the surfaces of volcanic rocks, as in Vesuvius, Aetna, &c.

Genus VI.—VITRIOL.

Pyramidal, prismatic. Taste, astringent. Hardness = 2.0, — 2.5. Sp. gr. = 1.8, — 2.3.

1. *Hemiprismatic, or Green Vitriol*.

Hemiprismatisches Vitriol-Salz, *Mohs*.—Eisen Vitriol, *Werner*.—Fer Sulfatée, *Haüy*.

Specific Character.—Prismatic. Combination hemiprismatic $\frac{P}{2} = 102^{\circ} 35'$, $P + \infty = 82^{\circ} 21'$. Cleavage =

$P + \infty$. Inclination of $P - \infty$ to $P + \infty = 99^{\circ} 23'$. Green. Hardness = 2.0. Sp. gr. = 1.8, — 2.9.

Description.—Colour green. Occurs regularly crystallized, in fibrous concretions, massive, stalactitic, botryoidal, and reniform. More or less translucent and transparent.

Constituent Parts.—Sulphuric acid 31.02, oxide of iron 27.19, water 41.79, = 100. *Kobell*.

Geognostic and Geographic Situations.—Occurs in coal and iron mines, both in Scotland and England.

2. *Tetartoprismatic Vitriol, or Blue Vitriol*.

Prismatisches Vitriol-Salz, *Mohs*.—Kupfervitriol, *Werner*.—Cuivre Sulfatée, *Haüy*.

Specific Character.—Prismatic. Combination, tetartoprismatic. Cleavage, two faces, one more distinct than the other; incidence, $149^{\circ} 2'$. Hardness = 2.5. Sp. gr. = 2.2, — 2.3.

Description.—Colour blue. Occurs distinctly crystallized, massive, stalactitic, and dentiform. More or less transparent and translucent.

Constituent Parts.—Oxide of copper 31.72, sulphuric acid, 31.72, water, 36.14.

Geognostic and Geographic Situations.—Occurs in copper mines in England and Ireland.

3. *Prismatic Vitriol, or White Vitriol*.

Prismatisches Vitriol-Salz, *Mohs*.—Zink-vitriol, *Werner*.—Zink sulfatée, *Haüy*.

Minera-
logy.

Specific Character.—Prismatic. $P = 127^\circ 27'; 126^\circ 45'; 78^\circ 5'$. $P + \infty = 90^\circ 42'$. Cleavage $Pr + \infty$ very perfect. White. Hardness = 2.0, — 2.5. Sp. gr. = 2.0, — 2.1.

Constituent Parts—Oxide of zinc 27.5, sulphuric acid, 20.0, water 50.0. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in mines where blende is met with, both in Flintshire and Cornwall.

Genus VII.—EPSOM SALT.

Prismatic. Taste bitter and saline. Hardness = 2.0, — 2.5. Sp. gr. = 1.7, — 1.8.

1. *Prismatic Epsom Salt*.

Prismatisches Bittersalz, *Mohs*. Natürlicher Bittersalz, *Werner*. Magnesie Sulfatée, *Haüy*.

Specific Character.—Prismatic. $P = 127^\circ 22'; 126^\circ 48'; 78^\circ 7'$. $P + \infty = 90^\circ 38'$. Cleavage $Pr + 8$, very perfect.

Description.—Colours white and grey. Occurs in crusts, botryoidal, reniform, and crystallized. Transparent or translucent.

Constituent Parts.—Magnesia 16.0, sulphuric acid 32.53, water 51.43.

Geognostic and Geographic Situations.—Occurs along with natural alum at Hurler near Paisley.

Genus VIII.—ALUM.

Tessular. Taste sweetish, astringent. Hardness = 2.0, — 2.5. Sp. gr. = 1.7, — 1.8.

1. *Octahedral Alum*.

Octaedrisches Alaun, *Mohs*.—Natürlicher Alaun, *Werner*.—Alumine Sulphatée Alcaline, *Haüy*.

Specific Character.—Tessular. Cleavage octahedral.

Description.—Colours white. Occurs in crystals; but more frequently in farinaceous efflorescences, stalactitic, and in fibrous concretions. Translucent.

Constituent Parts.—Alumina 10.8. Potash 10.1. Sulphuric acid 33.7. Water 45.4.—*Gmelin*.

Geognostic and Geographic Situations.—Generally occurs incrusting aluminous minerals, in which situation it is met with in various parts of Scotland and England.

Genus IX.—BORAX.

Borax-Salz, *Mohs*.

Prismatic. Taste feebly sweetish and alkaline. Hardness = 2.0, — 2.5. Sp. gr. = 1.7, — 1.8.

1. *Prismatic Borax*.

Prismatisches Borax-Salz, *Mohs*.—Soude Boratée, *Haüy*.

Specific Character.—Prismatic. $P = 150^\circ 9'; 120^\circ 20'; 67^\circ 3'$. $P + \infty = 52^\circ 53'$. Combination hemiprismatic, $\frac{P}{2} = 120^\circ 23'$. Cleavage $(Pr + \infty)^3 = 88^\circ 8'$. More distinct $\bar{Pr} + \infty$. (Fig. 32, 29.)

Description.—Colours white, grey, and green. Occurs crystallized, internally shining and resinous. Fracture, flat, conchoidal. Semitransparent.

Constituent Parts.—Soda 16.31. Boracic acid 36.59. Water 47.10.—*Berzelius*.

Geognostic and Geographic Situations.—Occurs in the soil, and in the water of springs in Thibet and Persia.

Genus X.—GLAUBERITE.

Brithyn-Salz, *Mohs*.

Prismatic. Taste feebly saline and astringent. Hardness = 2.5, — 3.0. Sp. gr. 2.75, — 2.85.

1. *Prismatic Glauberite*.

Prismatisches Brithyn-Salz, *Mohs*.—Glauberite, *Haüy*. *Specific Character.*—Prismatic. Pyramid unknown.

Combination hemiprismatic. Cleavage $\frac{Pr}{2}$, perfect. Indistinct $P + \infty = 104^\circ 28'$. (Fig. 35, 30.)

Description.—Colours white and yellow. Occurs crystallized in oblique four-sided prisms. Shining lustre. Fracture conchoidal. Transparent. Brittle.

Constituent Parts.—Sulphate of lime 49.0. Sulphate of soda 51.0.—*Brongniart*.

Geognostic and Geographic Situations.—Occurs in masses of rock-salt, associated with clay, at Villarubia near Ocanas, in the province of Toledo, in Spain.

CLASS II.

Specific gravity above 1.8. Tasteless.

Order I.—HALOIDE.¹

Not metallic. Streak white or grey. Hardness = 1.5, — 5.0. Sp. gr. = 2.2, — 3.3.

If pyramidal or prismatic, the hardness = 4.0, and less. If tessular, the hardness = 4.0. If single highly perfect faces of cleavage, the sp. gr. = 2.4, and less. If the hardness is under 2.5, the sp. gr. = 2.4, and less. If the sp. gr. = 2.4, and less, the hardness is under 2.5, and no resinous lustre.

Genus I.—GYPSUM.

Prismatic. Hardness = 1.5, — 3.5. Sp. gr. = 2.2, — 3.0.

If the sp. gr. is above 2.5, there are cleavages in three directions, perpendicular to each other, and of which two are more distinct than the other.

1. *Prismatoidal Gypsum, or Common Gypsum*.

Prismatoidisches Gyps-Haloid, *Mohs*.—Chaux sulfatée, *Haüy*.

Specific Character.—Prismatic. Pyramid = $149^\circ 33'; 135^\circ 32'; 54^\circ 52'$. $P + \infty = 110^\circ 30'$. Combination hemiprismatic, $\frac{P}{2} = 149^\circ 33'$. Cleavage, $Pr + \infty$, very

perfect and distinct, $\bar{Pr}$, $\bar{Pr} + \infty$, imperfect. (Fig. 41.) Hardness = 1.5, — 2.0. Sp. gr. = 2.2, — 2.4.

Description.—Most frequent colours white and grey; occurs also yellow, red, blue, green, brown, and even black. Occurs in regular crystals; in granular, scaly-granular, and fibrous distinct concretions; massive, disseminated, and dentiform. Lustre alternates from splendid to glimmering, and is pearly. Fracture splintery. Fragments indeterminate, angular, and blunt-edged. Alternates from transparent to translucent on the edges.

The transparent and highly crystallized varieties are named *selenite*; those in granular concretions, *foliated granular gypsum*; those disposed in fibrous concretion, *fibrous gypsum*; the splintery fracture characterizes the *compact gypsum*; while those varieties composed of scaly-granular concretions form the subspecies named *scaly-foliated gypsum*. Some varieties, composed of fine scaly or

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¹ From $\alpha\lambda\gamma$, salt; and $\tau\epsilon\sigma$, the appearance (nabitus).

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dusty and slightly cohering particles, are named *earthy gypsum*.

Constituent Parts.—Lime 33.0. Sulphuric acid 44.8. Water 21.0.—*Bucholz*.

Geognostic and Geographic Situations.—*Selenite*, the purest subspecies, occurs most frequently in what are called the gypsum and salt formations of the secondary class of rocks; also in metalliferous veins of different descriptions, and in various alluvial clays and marls. The *foliated granular* subspecies occurs in beds, in transition and secondary rocks,—being in the former intermixed with mica, in the latter with quartz, boracite, &c. The *compact variety* occurs in considerable abundance along with the granular in the secondary gypsum formation, and the *fibrous* is disposed in veins in the same formation, which also contains the *scaly-foliated* and the *earthy kinds*.

The salt mines in England afford examples of nearly all the subspecies, and several of them are also met with in Scotland.

2. Prismatic Gypsum, or Anhydrite.

Prismatisches Gyps-Haloide, *Mohs*.—Muriacit, *Werner*.—Chaux Anhydro-Sulphatée, *Haüy*.

Specific Character.—Prismatic. Pyramid = $121^{\circ} 32'$; $108^{\circ} 35'$; $99^{\circ} 7'$. Cleavage, $\text{Pr} = \infty$. $\text{Pr} + \infty$, very perfect. Less perfect $\text{P} = \infty$. Traces of $\text{P} + \infty$. (Fig. 29, 28, 27, 30.) Hardness = 3.0,—3.5. Sp. gr. = 2.7,—3.0.

Description.—Colours white, blue, red, and grey. Occurs crystallized; in granular, fibrous, and lamellar concretions; massive, and vermicularly convoluted or contorted. Lustre alternates from splendid to glistening, and is pearly. Fracture splintery and conchoidal. Alternates from transparent to translucent on the edges.

Constituent Parts.—Lime 41.75, sulphuric acid 55.0, muriate of soda, 1.0. *Klaproth*.

Geognostic and Geographic Situations.—Occurs massive, and in beds in the salt and secondary gypsum formations. Is frequently intermixed with rock-salt, also with stinkstone, saliniferous clay, and occasionally with ores of different kinds. Some varieties are met with in transition and primitive rocks. Several of the varieties are found in the red sandstones of England and Scotland.

Genus II.—CRYOLITE.

Prismatic. Cleavage in three directions, perpendicular to each other, of which one is more perfect than the others. Hardness = 2.5,—3.0. Sp. gr. = 2.9,—3.0.

1. Prismatic Cryolite.

Kryolite, *Werner*.—Prismatisches Kryon-Haloide, *Mohs*.—Alumine fluatée alcaline, *Haüy*.

Specific Character.—Prismatic. Pyramid unknown. Cleavage, $\text{P} = \infty$. Less distinct, $\text{Pr} + \infty$. $\text{Pr} + \infty$. Traces of P . (Fig. 27, 29, 28.)

Description.—Colours white, brown, and red. Occurs massive, disseminated, and in lamellar concretions. Internally shining, and lustre vitreous, inclining to pearly. Fracture uneven. Fragments cubical. Translucent. Brittle, and easily frangible.

Constituent Parts.—Alumina 24.40, soda 31.35, fluorine acid 44.25. *Berzelius*.

Geognostic and Geographic Situations. It has hitherto been found only in West Greenland, where it occurs in gneiss, associated with iron-pyrites and galena or lead-glance.

Genus III.—ALUMSTONE.

Alaun-Haloide, *Mohs*.—Alaunstein, *Werner*.

Rhombohedral. Hardness = 5.0. Sp. gr. = 2.4,—2.6.

1. Rhombohedral Alumstone.

Rhomboedrisches Alaun-Haloide, *Mohs*.

Specific Character.—Rhombohedral. Rhomboid unknown. Cleavage $\text{R} = \infty$. R .

Description.—Colours white, red, and rarely grey. Occurs massive, porous, and vesicular. Lustre feebly glimmering. Fracture uneven. Feebly translucent on the edges. Brittle, and easily frangible.

Constituent Parts.—Mont d'Or in Auvergne. Sulphuric acid 27.05, alumina 31.80, potash 5.79, silica 28.40, water and loss 3.72. *Cordier*.

Geognostic and Geographic Situations.—Occurs in beds and large irregular masses in porphyry in Hungary, and in veins and drusy cavities in aluminous rocks at Tolfa, near to Civita Vecchia.

Genus IV.—FLUOR.

Tessular. Hardness = 4.0. Sp. gr. = 3.0,—3.3.

1. Octahedral Fluor.

Octaedrisches Flus-Haloide, *Mohs*.—Chaux fluatée, *Haüy*.

Specific Character.—Tessular. Cleavage octahedral.

Description.—Colours white, grey, black, blue, green, yellow, red, and brown. Occurs regularly crystallized, in granular, prismatic, and lamellar concretions, massive, and disseminated. Lustre from splendid to feebly glimmering, and vitreous. Fracture even, inclining to splintery and to conchoidal. More or less transparent and translucent. Brittle, and easily frangible.

The varieties, with even fracture and feeble lustre, are named *compact fluor*; those in which the cleavage is distinct are named common or *foliated fluor*; and some rare, dull, earthy, and loosely aggregated varieties, which occur, incrusting other minerals, are described under the name *earthy fluor*.

Constituent Parts.—Lime 67.75, fluorine acid 32.25. *Klaproth*.

Geognostic and Geographic Situations.—It occurs in veins and beds in primitive gneiss, mica-slate, and clay-slate, in various remarkable metalliferous formations of cobalt, silver, tin, lead, copper, &c.; less frequently in transition rocks, and very abundantly in some secondary rocks, as limestone, and rarely in secondary porphyries. It is a rare mineral in Scotland, its principal localities being Monaltree, in Aberdeenshire, Banffshire, Papa Stour in Shetland, and Gourock in Renfrewshire. It is very abundant in several of the mining districts in England.

Genus V.—APATITE.

Rhombohedral. Hardness = 5.0. Sp. gr. = 3.0,—3.3.

1. Rhombohedral Apatite.

Rhomboedrisches Flus-Haloide, *Mohs*.—Apatit, *Werner*.—Chaux phosphatée, *Haüy*.

Specific Character.—Rhombohedral. $\text{R} = 88^{\circ} 41'$. Combination, dirhombohedral. 2. $\text{R} = 131^{\circ} 14'$; $111^{\circ} 20'$, ($\text{P} + \text{n}$)^m hemi-dirhombohedral, with parallel planes. Cleavage, $\text{R} = \infty$. $\text{P} + \infty$. $\text{H} = 5$. Sp. gr. = 3.0,—3.3.

Description.—Colours white, green, blue, red, yellow, and brown. Occurs regularly crystallized; in concretions which are granular, lamellar, and fibrous; massive and disseminated; lustre resinous, and varying from splendid to glimmering. Fracture conchoidal and uneven. Alternates from transparent to feebly translucent on the edges. Brittle, and easily frangible.

One set of varieties, in which the cleavage is very distinct, is named *foliated apatite*; another, in which the fracture is conchoidal, is named *conchoidal apatite*; and the varieties in which the fracture is uneven are named *phosphorite*.

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Constituent Parts.—Lime 55.75, phosphoric acid 44.25.

Klaproth.

Geognostic and Geographic Situations.—Occurs in gneiss, near Kincardine, in Ross-shire; in the same rock in the Shetland Islands; and in veins in greenstone, in the Island of Rume. Several varieties are met with in Cornwall.

Genus VI.—LIMESTONE.

Kalk-Haloide, *Mohs*.

Rhombohedral, prismatic. Cleavage, rhombohedro-paramous, prismatoidal. Hardness = 3.0, — 4.5. Sp. gr. = 2.5, — 3.2. If prismatic, the specific gravity = 3.0 and less. If the hardness is above 4.0, the specific gravity = 2.8 and more. If specific gravity = 2.9 and more, the hardness = 2.8 and more.

1. Prismatic Limestone, or Aragonite.

Prismatisches Kalk-Haloide, *Mohs*.—Aragon, *Werner*.

—Aragonite, *Haüy*.

Specific Character.—Prismatic. Pyramid = $113^{\circ} 44'$; $93^{\circ} 43'$; $122^{\circ} 10'$. $P + \infty = 105^{\circ} 23'$. Cleavage, $Pr - 1 = 109^{\circ} 28'$. $(Pr + \infty)^3 = 64^{\circ} 4'$. More distinct, $Pr + \infty$. (Fig. 42.) Hardness = 3.5, — 4.0. Sp. gr. = 2.6, — 3.0.

Description.—Colours white, grey, green, and violet-blue. Occurs regularly crystallized; also in prismatic concretions and massive. Lustre vitreous, inclining to resinous, and shining and glistening. Fracture conchoidal passing into uneven. Translucent and transparent. Brittle, and easily frangible.

Constituent Parts.—Carbonate of lime 94.82, carbonate of strontites 4.08, water 0.98. *Stromeyer*.

Geognostic and Geographic Situations.—Occurs along with galena in the lead-mines of Leadhills, and in secondary trap-rocks in different parts of Scotland.

2. Rhombohedral Limestone.

Rhomboedrisches Kalk-Haloide, *Mohs*.—Chaux carbonatée, *Haüy*.—Kalk-spath, *Werner*.

Specific Character.—Rhombohedral. Rhombohedron = $105^{\circ} 5'$. Cleavage, R. Hardness = 3.0. Sp. gr. = 2.5, — 2.8.

Constituent Parts.—The purest kind of this species, named calcareous spar, is composed of lime 56.15, carbonic acid 43.70.

Description.—Colours very varied, but of all the tints, white and grey are the most frequent; besides these, the following kinds also occur, viz. red, blue, green, yellow, brown, and rarely black. Occurs regularly crystallized, and of all known minerals, exhibits the greatest number of varieties of the rhombohedral series of crystallization; also in granular, prismatic, tabular, and globular distinct concretions. Its other forms are massive, disseminated, globular, botryoidal, reniform, tuberoso, stalactitic, tabular, claviform, coralloidal, cellular, and curtain-shaped. Its lustre varies from splendid to dull, and is vitreous, inclining sometimes to pearly, sometimes to resinous. Fracture splintery, conchoidal, earthy, and uneven. Alternates from transparent to opaque. Generally brittle, and easily frangible.

Those varieties which are regularly crystallized, and possess high degrees of transparency, are named *calcareous spar*; those in angulo-granular distinct concretions, with a lower lustre and transparency than the former, are the *foliated granular limestone*, or *crystalline marble* of authors; the varieties with splintery or conchoidal fractures are named *compact limestone*; other varieties having a grey or brown colour, dull earthy fracture, and which, on rubbing, give out a sulphureo-bituminous smell, are named

stinkstone; the black varieties in granular and prismatic concretions, or with a compact fracture, with a glimmering or shining lustre, and low degree of translucency on the edges or complete opacity, and which, on rubbing, yield a sulphureo-bituminous odour, are named *anthraconite*; those limestones which have the oolitic structure, or are composed of spherical granular concretions, set on a marly basis, are named *roestone* or *oolite*; the soft varieties with earthy fracture and white colour are named *chalk*; the varieties with dull fracture surface, in loosely cohering pieces and crusts, and so light as nearly to swim upon water, are named *agaric mineral*; the fibrous varieties are named *common fibrous limestone* or *satin spar*, and *fibrous calc-sinter*, or calcareous alabaster; the earthy-looking opaque varieties that occur in many particular external shapes, near calcareous springs, and on the borders of lakes, are named *calc-tuff*; while the varieties in spherical round granular concretions, and concentric lamellar concretions, found near hot springs, are named *peastone*; the *slate-spar* of mineralogists is a variety in lamellar concretions, with a beautiful pearly lustre and feeble translucency; varieties with earthy fracture, more or less inclined to splintery and conchoidal, are named *marl*; and, lastly, the opaque dull black varieties, with slaty fracture, are named *bituminous marl-slate*.

Geognostic Situation.—This mineral is one of the most abundant and widely distributed with which we are acquainted. Calcareous spar, one of its principal kinds, occurs in every rock from granite to the newest member of the secondary series. It generally occurs in veins with numerous metalliferous minerals, and assists in an eminent degree in characterizing the vast host of mineral veins in primitive, transition, and secondary rocks. In the state of granular, foliated, and compact limestones, also in the form of oolite, chalk, and lucullite, it forms beds, hills, mountains, and even ranges of mountains. The beautiful fibrous limestone or satin-spar, occurs in veins in clay-slate, and in rocks of the coal formation, while all the beautiful forms of calc-sinter are met with ornamenting the walls and floors of caverns in limestone and other formations; calc-tuff abounds around cold, and also warm springs, frequently incrusting organic bodies, forming the calcareous incrustations so well known to mineralogists. Peastone is also a production of warm springs. The white, porous, and nearly supernatent mineral agaric incrusts rocky cliffs, particularly in limestone hills, and the rare variety, named slate-spar, has hitherto been found only in primitive limestone.

Geographic Situation.—England and Scotland abound in interesting varieties of calcareous-spar, and the mountains, hills, and valleys of Great Britain afford numerous localities of many of the different kinds of marble, limestone, chalk, marl, Lucullite, and oolite, while its calcareous springs, and caves and caverns, exhibit numerous deposits of calc-tuff and of calc-sinter.

3. Dolomite or Macrotypous¹ Limestone.

Macrotypes Kalk-Haloide, *Mohs*.—Braunspath, Rhomb-spath, Dolomite, *Werner*.—Chaux carbonatée ferrifère perlée, Chaux carbonatée magnésifère, *Haüy*.

Specific Character.—Rhombohedral. Rhombohedron $106^{\circ} 15'$. Cleavage, rhombohedral. Hardness = 3.5, — 4.0. Sp. gr. = 2.8, — 2.95.

Description.—Colours white, grey, brown, red, and green. Occurs crystallized in rhomboids, in granular and prismatic concretions; massive, disseminated, globular, stalactitic, reniform, and with tabular and pyramidal impressions. Lustre varies from shining to glimmering, and is pearly, sometimes inclining to vitreous. Fracture splintery, conchoidal, and slaty. Varies from transparent to translucent on the edges. Brittle, and easily frangible.

¹ From μακρὸς long; and τύπος, the type (fundamental form).

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logy.

The white varieties in small and fine granular concretions, which are sometimes so loosely aggregated as to separate by the mere pressure of the finger, are the *dolomite-marble* of mineralogists; the *magnesian limestone* of England is a dolomite with yellow or yellowish brown colours; the green varieties are described under the name *Miemite*, from Miemo in Tuscany, where they were first found; the brown, red, reddish-white, and pearl-grey varieties, with very distinct pearly lustre, are arranged together, and described under the names *brown spar* and *pearl spar*.

Constituent Parts.—Carbonate of lime 68.0, carbonate of magnesia 25.5, alumina 2.0, carbonate of iron 1.0, water 2.0. *Klaproth*.

Geognostic and Geographic Situations.—The dolomite marble occurs in the island of Iona; the yellow dolomite constitutes a secondary limestone formation very abundant in England; the brown spar and pearl spar are not unfrequent in the lead mines of Scotland and England.

4. *Brunnerite* or *Brachytypous*¹ *Limestone*.

Brachytypes Kalk-Haloid, *Mohs*.—Rautenspath, *Werner*.—Chaux carbonatée magnésifère, *Haiiy*.

Specific Character.—Rhombohedral. Rhombohedron = $107^{\circ} 22'$. Cleavage rhombohedral. Hardness = 4.0, —4.5. Sp. gr. = 3.0, —3.2.

Description.—Colours white, grey, and yellow. Occurs crystallized in rhombs; also massive and disseminated. Lustre splendid and vitreo-pearly. Fracture imperfect conchoidal. More or less translucent. Brittle, and easily frangible.

Constituent Parts.—Magnesia, 41.06, protoxide of iron 8.57, oxide of manganese 0.43, carbonic acid 48.94. *Stromeyer*.

Geognostic and Geographic Situations.—Occurs imbedded in chlorite-slate on the banks of Loch Lomond, and associated with galena, copper-pyrites, and blende, near Newton Stewart, in Galloway. It is named in honour of Count Breunner.

5. *Ankerite* or *Paratomous Limestone*.

Specific Character.—Rhombohedral. Cleavage parallel to a rhombohedron of $106^{\circ} 12'$. $H = 3.5$, —4.0. Sp. gr. = 2.95, —3.1. Is a compound of carbonate of lime and carbonate of iron.

Geognostic and Geographic Situations.—Found in the Styrian mines. Is named in honour of Professor Anker.

Order II.—BARYTE.

Not metallic. No metallic-pearly lustre. Streak white, grey, or orange-yellow. $H = 2.5$, —5.0. Sp. gr. = 3.3, —7.3. If cleavage monotonous, the specific gravity = 4.0 and less, or = 5.0 and more. Not elastic, not flexible, in thin folia. If lustre adamantine or imperfect metallic, the sp. gr. = 5.0 and more. If streak orange-yellow, the sp. gr. = 6.0 and more. If $H = 5.0$, and sp. gr. less than 4.5, the streak is white. If the sp. gr. is less than 4.0, and $H = 5.0$, the cleavage is diprismatic.

Genus I.—SPARRY IRON.

Rhombohedral. Cleavage paratomous. Hardness = 3.5, —4.5. Sp. gr. = 3.3, —3.9.

1. *Rhombohedral Sparry Iron*.

Brachytypen Parachros Baryte, *Mohs*.—Spath Eisenstein, *Werner*.—Fer Oxyde Carbonaté, *Haiiy*.

Specific Character.—Rhombohedral. Rhombohedron = $107^{\circ} 0'$. Cleavage rhombohedral. $H = 3.5$, —4.5. Sp. gr. = 3.3, —3.9.

Description.—Colours yellow, white, brown, and black. Occurs crystallized in rhombohedrons; also in granular concretions, massive and disseminated. Internally, lustre

pearly, and varying from shining to glimmering, and even to splendent. Fracture sometimes splintery. Translucent on the edges. Rather brittle, and easily frangible.

Constituent Parts.—Protoxide of iron 57.50, carbonic acid 36.00, oxide of manganese 3.30, lime 1.25. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in metalliferous veins, and in common veins, in primitive, transition, and secondary rocks in different parts of Great Britain and Ireland. The common *clay ironstone* of the coal formation, the most important of ores, is an impure kind, of this species.

Genus II.—RED MANGANESE.

Hardness = 3.5. Sp. gr. = 3.3, —3.6.

1. *Rhombohedral Red Manganese*.

Macrotyper Parachros Baryte, *Mohs*.—Rother Braunstein, *Werner*. Manganese Oxyde Carbonaté, *Haiiy*.

Specific Character.—Rhombohedral. Rhombohedron = $106^{\circ} 51'$. Cleavage, rhombohedral.

Description.—Colours red and brown. Occurs in granular concretions, also in fibrous concretions, which are scopiformly and stellularly arranged, massive, and reniform. Lustre varies from shining to glimmering, and pearly. Fracture splintery. More or less translucent on the edges; in some rare varieties translucent. Brittle, and rather easily frangible.

The varieties with distinct cleavage are named *foliated red manganese*; those in fibrous concretions, *fibrous red manganese*; and the splintery varieties, *compact red manganese*.

Constituent Parts.—Oxide of manganese 54.60, carbonic acid 33.75, oxide of iron 1.87, silica 4.37, lime 2.50. *Du Menil*.

Geognostic and Geographic Situations.—Occurs at Kapnic in Transylvania, and at Catharinenberg in Siberia.

Genus III.—CALAMINE.

Zinc-Baryt, *Mohs*.

Rhombohedral. Prismatic. Hardness = 5.0. Sp. gr. = 3.3, —4.5. If rhombohedral, the sp. gr. above 4.0.

1. *Prismatic Calamine, or Silicate of Zinc*.

Prismatischer Zinc-Baryt, *Mohs*. Zink Oxyde, *Haiiy*.

Specific Character.—Prismatic. Pyramid = $134^{\circ} 59'$; $99^{\circ} 56'$; $96^{\circ} 56'$. $P + \infty = 118^{\circ} 29'$. Cleavage, $Pr = 120^{\circ}$. More distinct, $(Pr + \infty)^3 = 80^{\circ} 4'$. (Fig. 43.) Hardness 5.0. Sp. gr. = 3.3, —3.6.

Description.—Most frequent colours white and yellow; also green, grey, yellow, and brown; and with curved striped colour delineations. Occurs regularly crystallized, and in distinct concretions, which are scopiform radiated, and scopiform fibrous, granular, and curved lamellar. Massive, in crusts, stalactitic, reniform, botryoidal, and cellular. Internally alternates from glistening to dull, and lustre pearly, inclining to adamantine. Fracture small and fine-grained, uneven. Varies from transparent to opaque.

Constituent Parts.—Oxide of zinc 66.83, silica 24.89, water 7.46. *Berthier*.

Geognostic and Geographic Situations.—Occurs in veins of galena, in greywacke, and clay-slate, and in beds, and imbedded masses in secondary limestone. Is found in the lead mines of Wanlockhead, and in the mines of Flintshire and Leicestershire.

2. *Rhombohedral Calamine or Carbonate of Zinc*.

Rhomboedrischer Zinc-baryt, *Mohs*.—Galmei, *Werner*.—Zinc carbonaté, *Haiiy*.

¹ From *βραχος*, short, and *τύπος*, the type.

Mineralogy. *Specific Character.*—Rhombohedral. Rhombohedron = 110° (nearly.) Cleavage rhombohedral. Hardness = 5.0. Sp. gr. = 4.2,—4.5.

Description.—Colours white, grey, green, yellow, and brown. Occurs regularly crystallized, and in distinct concretions, which are radiated, granular, and curved lamellar; massive, corroded, reniform, stalactitic, botryoidal, and cellular. Internally ranges from shining to dull, and is pearly. Fracture uneven, splintery, and flat conchoidal. Ranges from transparent to opaque.

Constituent Parts.—Oxide of zinc 65.20, carbonic acid 34.80. *Smithson.*

Geognostic and Geographic Situations.—Occurs in beds, veins, nests, filling up or lining hollows, in transition limestone and in secondary limestone. Derbyshire, Somersetshire, Flintshire, and Durham, afford numerous localities of this mineral.

Genus IV.—TUNGSTEN, or SCHEELIUM.

Pyramidal. Hardness = 4.0,—4.5. Sp. gr. = 6.0,—6.1.

1. *Pyramidal Tungsten.*

Pyramidaler Scheel-Baryt, *Mohs.*—Schwerstein, *Werner.*—Scheelin Calcaire, *Haüy.*

Specific Character.—Pyramidal. Pyramid = 107° 27'; 113° 35'. Combination hemi-pyramidal with parallel planes. Cleavage, $P + 1 = 100^\circ 8'$; $130^\circ 20'$. P . Traces in direction of $P - \infty$.

Description.—White is the principal colour; but other varieties, as brown and orange yellow, occasionally occur. Sometimes crystallized, and also in distinct concretions, which are granular, prismatic, and curved lamellar. Occurs massive and disseminated. External lustre shining and splendid; internal lustre shining and resinous. Fracture uneven or conchoidal. More or less translucent, seldom transparent.

Constituent Parts.—Lime 19.40, oxide of scheelium 80.24. *Berzelius.*

Geognostic and Geographic Situations.—Occurs along with tinstone, wolfram, magnetic iron-ore, and brown iron-ore, in Cornwall, &c.

Genus V. BARYTE.

Prismatic. Hardness = 3.0,—4.0. Sp. gr. 3.6,—4.7.

1. *Peritomous Baryte, or Strontianite.*

Peritomer Hal-Baryt, *Mohs.*—Strontian, *Werner.*—Strontiane Carbonaté, *Haüy.*

Specific Character.—Prismatic. Pyramid unknown. Cleavage, $P + \infty = 117^\circ 19'$; less distinct $\bar{P}r$. Traces according to $\bar{P}r + \infty$. (Fig. 46.) Hardness = 3.5. Sp. gr. 3.6,—3.8.

Description.—Colours green and grey. Occurs regularly crystallized, and in distinct concretions, which are scopiform radiated, and scopiform fibrous. Lustre shining, glistening, and pearly. Fracture uneven. More or less translucent. Brittle, and easily frangible.

Constituent Parts.—Strontia 61.21, carbonic acid 30.20, water 8.59. *Hope.*

Geognostic and Geographic Situations.—Occurs at Strontian in Scotland in veins of lead-glance that traverse gneiss.

2. *Di-prismatic Baryte or Witherite.*

Di-prismatischer Hal-baryt, *Mohs.*—Witherit, *Werner.*—Baryte carbonaté, *Haüy.*

Specific Character.—Prismatic. Pyramid unknown. Cleavage, $P + \infty = 118^\circ 30'$. $\bar{P}r + \infty$. $\bar{P}r + 1$. (Fig. 46.) Hardness = 3.0,—3.5. Sp. gr. = 4.2,—4.4.

Description.—Colours white, grey, and yellow. Occurs regularly crystallized, and also in distinct concretions, which are radiated and granular. Occurs massive, cellular, globular, botryoidal, reniform, and stalactitic. Lustre shining and resinous. Fracture uneven, inclining to splintery. Translucent. Brittle, and easily frangible.

Constituent Parts.—*Witherit.* Baryta 79.66, carbonic acid 20.00, water 0.33. *Bucholz.*

Geognostic and Geographic Situations.—Occurs abundantly in the lead mines of Cumberland, and at Anglesark in Lancashire.

3. *Prismatic Baryte, or Heavy-Spar.*

Prismatischer Hal-baryte, *Mohs.*—Schwerspath, *Werner.*—Baryte sulphatée, *Haüy.*

Specific Character.—Prismatic. $\bar{P}r = 105^\circ 6'$; $(\bar{P}r + \infty)^2 = 77^\circ 27'$. Cleavage $\bar{P}r = 78^\circ 18'$. $\bar{P}r + \infty$. (Fig. 45.) Less distinct, $P - \infty$. (Fig. 33, 20, 27, 28.) Hardness = 3.0,—3.5. Sp. gr. = 4.1,—4.7.

Description.—Colours white, grey, black, blue, green, yellow, red, and brown. Occurs regularly crystallized; also in granular, lamellar, fibrous, and prismatic distinct concretions; massive, disseminated, reniform, botryoidal, and globular. Lustre alternates from splendid to glimmering, and resinous or pearly, inclining to vitreous. Fracture uneven, splintery, and earthy. Alternates from transparent to opaque. Brittle, and very easily frangible.

The varieties with uneven and splintery fracture are named *compact h. spar*; those in fine granular concretion *granular h. spar*; the lamellar varieties are named *straight or curved lamellar h. spar*, according to the direction of the lamellar concretion; the fibrous varieties *fibrous h. spar*; the radiated varieties *radiated h. spar*; those in prismatic concretions *prismatic h. spar*; the varieties which, on rubbing, emit a hepatic smell, *fetid h. spar*, or *hepatite*; and those which occur in the earthy or powdery state, *earthy h. spar*.

Constituent Parts.—Baryta 66.00, sulphuric acid 34.00. *Berthier*

Geognostic and Geographic Situations.—It occurs in veins, either alone or associated with various metalliferous formations of silver, copper, lead, cobalt, antimony, manganese, zinc, arsenic, iron, &c. in rocks of the primitive, transition, and secondary classes. There are numerous localities of this mineral in Scotland, England, and Ireland.

4. *Prismatoidal Baryte, or Celestine.*

Prismatoidischer Hal-baryt, *Mohs.*—Coelestin, *Werner.*—Strontiane sulphatée, *Haüy.*

Specific Character.—Prismatic. $\bar{P}r = 103^\circ 58'$. $(\bar{P} + \infty)^2 = 78^\circ 35'$. Cleavage, $\bar{P}r = 76^\circ 2'$. More distinct. $\bar{P}r + \infty$. Less distinct $P - \infty$. Hardness = 3.0,—3.5. Sp. gr. = 3.6,—4.0.

Description.—Colours white, blue, and red. Occurs regularly crystallized; in granular, fibrous, and radiated distinct concretions; massive and stalactitic. Lustre alternates from splendid to glimmering, and is pearly. Ranges from transparent to translucent on the edges.

Constituent Parts.—Strontia 58.00, sulphuric acid 42.00. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in limestone, in red sandstone, and gypsum, where it is associated with sulphur, and in vesicular cavities in amygdaloid. It has been found in sandstone near Inverness; in the amygdaloid of the Calton Hill; in the neighbourhood of Bristol; and near Knaresborough, in Yorkshire.

Mineralogy.

Genus VI.—LEAD-SPAR.

Blei-baryt, *Mohs*.

Rhombohedral, pyramidal, prismatic. Hardness = 2.5, —4.0. Sp. gr. = 6.0,—7.3. If the hardness is above 3.5, the sp. gr. = 6.5, and more.

1. *Di-prismatic Lead-Spar, or White and Black Lead-Spars.*

Di-prismatischer Blei-baryt, *Mohs*.—Plomb carbonatée, *Häuy*.

Specific Character.—Prismatic. $P = 130^\circ 0'$; $108^\circ 28'$; $92^\circ 19'$. Cleavage, $Pr = 117^\circ 13'$. $(Pr + \infty)^3 = 69^\circ 20'$. (Fig. 43.) Hardness = 3.0,—3.5. Sp. gr. = 6.3,—6.6.

Description.—Principal colour white, occurs also black, yellow, brown, and grey. Occurs regularly crystallized; massive and cellular. Lustre externally ranges from splendid to shining; internally from shining to glistening, and is adamantine, inclining more or less to resinous and imperfect metallic. Fracture uneven and conchoidal. Ranges from transparent to opaque. Streak greyish-white.

Constituent Parts.—Oxide of lead 82.0, carbonic acid 16.0, water 2.0. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in veins in granite, gneiss, mica-slate, and clay-slate; also in limestone, greywacke, and in various secondary formations. Well known localities are Leadhills and Wanlockhead.

2. *Rhombohedral Lead-Spar, or Green and Brown Lead-Spars.*

Rhomboedrischer Blei-Baryt, *Mohs*.—Plomb phosphaté, *Häuy*.

Specific Character.—Rhombohedral. $R = 88^\circ 29'$; $2(R) = 131^\circ 5'$; $111^\circ 48'$. $P = 142^\circ 12'$; $80^\circ 44'$. Cleavage P . $P + \infty$. Both imperfect. Hardness = 3.5,—4.0. Sp. gr. = 6.9,—7.3.

Description.—Colours green, brown, and sometimes yellow and white. Occurs regularly crystallized; also in granular, radiated, and curved lamellar concretions. Lustre externally shining, internally glistening, and resinous. Fracture uneven or splintery. Ranges from translucent to translucent on the edges. Streak white.

Constituent Parts.—Oxide of lead 78.5, phosphoric acid 19.73, muriatic acid 1.65.

Geognostic and Geographic Situations.—Occurs in veins, and most abundantly in their upper part, in various rocks of the primitive, transition, and secondary classes, where it is associated with galena, white lead-spar, &c. Leadhills and Wanlockhead are well known localities.

3. *Hemi-Prismatic Lead-Spar, or Red Lead-Spar.*

Hemi-prismatischer Blei-Baryt, *Mohs*.—Roth Bleierz, *Werner*.—Plomb chromaté, *Häuy*.

Specific Character.—Prismatic. Pyramid unknown. Combination hemi-prismatic. Cleavage, $P + \infty = 90^\circ$ (nearly). $Pr + \infty$, $Pr - \infty$. (Fig. 30, 29, 28.) Hardness = 2.5. Sp. gr. = 6.0,—6.1.

Description.—Colour hyacinth-red. Occurs regularly crystallized; also massive, and in flakes. Internally shining or splendid, and lustre adamantine. Fracture uneven, sometimes imperfect conchoidal. More or less translucent. Streak between lemon-yellow and orange-yellow. Nearly sectile, and easily frangible.

Constituent Parts.—Oxide of lead 63.96, chromic acid 36.40. *Thenard*.

Geognostic and Geographic Situations.—Occurs in a granular quartz rock, associated with brown ironstone, iron-pyrites, green lead-spar, native gold, galena, and quartz, in Siberia; also in sandstone in the Brazils.

4. *Pyramidal Lead-Spar, or Yellow Lead-Spar.*

Pyramidaler Blei-Baryt, *Mohs*.—Gelb Bleierz, *Werner*.—Plomb molybdaté, *Häuy*.

Specific Character.—Pyramidal. Pyramid = $99^\circ 40'$; $131^\circ 35'$. Cleavage P . less distinct. $P - \infty$. Hardness = 3.0. Sp. gr. = 6.5,—6.9.

Description.—Colour yellow. Occurs crystallized; also massive, in crusts, and cellular. Externally generally splendid and shining; internally shining or glistening, and lustre resino-adamantine. Fracture uneven and conchoidal. Translucent, or translucent on the edges.

Constituent Parts.—Oxide of lead 58.40, molybdic acid 38.00, oxide of iron 2.08. *Hatchet*.

Geognostic and Geographic Situations.—Occurs in compact limestone, at Bleiberg in Carinthia; also in France and Saxony.

5. *Prismatic Lead-Spar, or Sulphate of Lead.*

Prismatischer Blei-Baryt, *Mohs*.—Vitriol Bleierz, *Werner*.—Plomb sulphaté, *Häuy*.

Specific Character.—Prismatic. Pyramid = $104^\circ 55'$; $(P + \infty)^2 = 78^\circ 45'$. Cleavage, $Pr = 76^\circ 11'$. More distinct $Pr + \infty$. (Fig. 45.) Hardness = 3.0. Sp. gr. 6.2,—6.3.

Description.—Colour white, seldom green or wine yellow, or blue (owing to blue malachite). Occurs regularly crystallized; in granular distinct concretions; also massive and disseminated. Lustre adamantine, and ranging from splendid to shining. Fracture conchoidal. Transparent or translucent.

Constituent Parts.—Oxide of lead 72.47, sulphuric acid 26.09, water 0.12, silica 0.51, *Stromeyer*.

Geognostic and Geographic Situations.—Occurs in galena veins, at Leadhills and Wanlockhead and also in the Pary's Mine in Anglesea.

Order III.—KERATE.¹

Not metallic. Streak white or grey. No single distinct cleavage. Hardness = 1.0,—2.0. Sp. gr. = 5.5,—6.5.

Genus I.—CORNEOUS SILVER, OR CHLORIDE OF SILVER.

Hardness = 1.0,—2.0. Sp. gr. = 5.5,—6.5.

1. *Hexahedral Corneous Silver.*

Hexedrisches Perl Kerat, *Mohs*.—Hornerz, *Werner*.—Argent muriaté, *Häuy*.

Specific Character.—Tessular. Cleavage not visible. Malleable. Sectile.

Description.—Colour pearl-grey, which passes into white, blue, and green; on exposure to light becomes brown. Occurs crystallized; in prismatic and granular concretions; massive, and in flakes. Lustre ranges from shining to glistening and is resinous. Fracture conchoidal. Translucent, or feebly translucent on the edges. Becomes shining in the streak.

Constituent Parts.—Silver 76.0, chlorine 24.0.

Geognostic and Geographic Situations.—Occurs in silver-mines in Siberia, America, and has also been found in Cornwall.

Genus II.—CORNEOUS MERCURY, OR MURIATE OF MERCURY.

Hardness = 1.0,—2.0. Sp. gr. 6.4,—6.5.

1. *Pyramidal Corneous Mercury.*

Pyramidales Perl Kerat, *Mohs*.—Quecksilber Hornerz, *Werner*.—Mercure muriaté, *Häuy*.

¹ From *κερας* horn, as the minerals of this order resemble horn in external aspect.

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Specific Character.—Pyramidal. $P = 98^\circ 4'$; $136^\circ 0'$. Cleavage $P + \infty$, imperfect. Sectile.

Description.—Colour grey. Occurs generally in very minute crystals in vesicular cavities. Lustre shining and adamantine. Faintly translucent.

Constituent Parts.—Oxide of mercury 76.0, muriatic acid 16.4, sulphuric acid 7.6. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in the mercury-mines of Almaden, Idria, and Bohemia.

Order IV.—MALACHITE.

Not metallic. Colour blue, green, brown. No single distinct faces of cleavage. Hardness = 2.0,—5.0. Sp. gr. = 2.0,—4.6. If brown, in colour or in streak, the hardness = 3.0, and less; and the specific gravity above 2.5. If white in the streak, the specific gravity = 2.2, and less; and the hardness under 3.0.

Genus I.—COPPER GREEN, OR CHRYSOCOLLA.

Staphylin Malachit, *Mohs.*

Uncleavable. Hardness = 2.0,—3.0. Sp. gr. = 2.0,—2.2.

1. Uncleavable Copper-Green.

Untheilbarer Staphylin-Malachite, *Mohs.*—Kupfergrün, *Werner.*—Cuivre carbonaté, *Haüy.*

Specific Character.—Reniform, botryoidal, massive. Fracture conchoidal, shining. Streak white.

Description.—Colour green. Occurs massive, disseminated, in crusts, reniform, and botryoidal. Lustre shining, glistening, and resinous. Fracture small, conchoidal. Ranges from translucent to translucent on the edges. Colour does not change in the streak.

Constituent Parts.—Oxide of copper 50.0, silica 26.0, water 17.0, carbonic acid 7.0. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in copper-mines in Cornwall.

Genus II.—LIRICONITE.¹

Lirikon-Malachite, *Mohs.*

Tessular, prismatic. Hardness = 2.0,—2.5. Sp. gr. = 2.8,—3.0.

1. Prismatic Liriconite, or Lenticular Arseniate of Copper.

Prismatischer Lirikon-Malachite, *Mohs.*—Linsenerz, *Werner.*—Cuivre arseniaté, *Haüy.*

Specific Character.—Prismatic. $\bar{P}r = 71^\circ 59'$. $P + \infty = 119^\circ 45'$. Cleavage, $\bar{P}r$. $P + \infty$, imperfect. (Fig. 35, 30.) Streak pale verdigris-green,...Sky-blue. Hardness = 2.0,—2.5. Sp. gr. = 2.8,—3.0.

Description.—Colour blue, inclining more or less to verdigris-green. Occurs regularly crystallized. Lustre shining, glistening, and pearly, passing to vitreous. Fracture uneven. Translucent. Brittle, and uncommonly easily frangible.

Geognostic and Geographic Situations.—Occurs in the copper-mines of Cornwall.

2. Hexahedral Liriconite, or Cubical Arseniate of Iron.

Hexaedrischer Lirikon-Malachite, *Mohs.*—Wurfelerz, *Werner.*—Fer arseniaté, *Haüy.*

Specific Character.—Tessular. Combination semi-tessular, with inclined planes. Cleavage, hexahedral. Streak pale olive-green,...brown. Hardness = 2.5. Sp. gr. = 2.9,—3.0.

Description.—Colour green. Occurs regularly crystallized, and massive. Lustre glistening and vitreo-resinous. Translucent, or translucent on the edges.

Constituent Parts.—Oxide of iron 40.56, arsenic acid 38.00, oxide of copper 0.60, silica 0.35, water 19.57. *Berzelius.*

Geognostic and Geographic Situations.—Occurs in the copper-mines of Cornwall.

Genus III.—OLIVENITE.

Oliven-Malachit, *Mohs.*

Prismatic. Cleavage very imperfect. Colour neither blue nor bright green. Streak olive-green—brown. Hardness = 3.0,—4.0. Sp. gr. = 3.6,—4.6.

1. Prismatic Olivenite, or Prismatic Arseniate of Copper.

Prismatischer Oliven-Malachit, *Mohs.*—Olivenerz, *Werner.*—Cuivre arseniaté, *Haüy.*

Specific Character.—Prismatic. $\bar{P}r = 110^\circ 50'$. $P + \infty = 92^\circ 30'$. Cleavage, $\bar{P}r$, $P + \infty$. (Fig. 30.) Streak olive-green,—brown. Hardness = 3.0. Sp. gr. = 4.2,—4.6.

Description.—Principal colour olive-green, also yellow, brown, and white. Occurs regularly crystallized; in concretions which are scopiform fibrous, angulo-granular, and curved lamellar; massive and in drusy crusts. Lustre ranges from splendid to glimmering, and is resinous, inclining to pearly, or pearly. Ranges from transparent to opaque.

Constituent Parts.—Oxide of copper 50.62, arsenic acid 45.00, water 3.50. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in the copper-mines of Cornwall.

2. Diprismatic Olivenite or Phosphate of Copper of Libethen.

Diprismatischer Oliven-Malachit, *Mohs.*

Specific Character.—Prismatic. $\bar{P}r = 111^\circ 58'$. $P + \infty = 95^\circ 2'$. Cleavage $+ \bar{P}r + \infty$. $\bar{P}r + \infty$, also $\bar{P}r$ and $P + \infty$. Streak olive-green. Hardness = 4.0. Sp. gr. = 3.6,—3.8.

Description.—Colours grass, olive, leek, and pistachio-green. Occurs regularly crystallized. Lustre vitreous and pearly. Fracture conchoidal. Ranges from semitransparent to translucent.

Constituent Parts.—Oxide of copper 63.0, phosphoric acid 28.7, water 8.4. *Berthier.*

Geognostic and Geographic Situations.—Occurs in drusy cavities in micaceous clay-slate, with quartz and tile-ore; sometimes also with copper-pyrites, at Libethen, in Hungary.

Genus IV.—BLUE MALACHITE, OR BLUE COPPER.

Lazur Malachit, *Mohs.*

Prismatic. Streak and colour blue. Hardness = 3.5,—4.0. Sp. gr. = 3.5,—3.7,—3.9.

1. Prismatic Blue Malachite.

Prismatischer Lazur Malachit, *Mohs.*—Kupferlazur, *Werner.*—Cuivre carbonaté bleu, *Haüy.*

Specific Character.—Prismatic. Hemiprismatic $\frac{P}{2} = 116^\circ 7'$. $(\bar{P} + \infty)^2 = 59^\circ 14'$. Cleavage $(\bar{P} + \infty)^2$. Less distinct $P - \infty$. Traces according to $\bar{P}r = 99^\circ 32'$.

Description.—Colours blue. Occurs regularly crystal-

¹ From λειρος, pale, and πορρα, dust (the streak).

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lized in concretions which are scopiform and stellate, radiated, and also curved lamellar; massive, globular, botryoidal, reniform, stalactitic, and cellular. Lustre ranges from shining to glimmering, and is vitreo-resinous. Fracture conchoidal. Ranges from transparent to translucent on the edges.

A variety, in dull and fine dusty particles, is named *earthy blue malachite*, while the other varieties are denominated *radiated blue malachite*.

Constituent Parts.—Copper 56.0, oxygen 12.5, carbonic acid 2.5. *Vauquelin*.

Geognostic and Geographic Situations.—Occurs in mineral veins and in beds in gneiss, mica-slate, greywacke, limestone, and red sandstone. It occurs at the Lead Hills, and in various English copper and lead mines.

* *Velvet Blue Copper*.

Kupfersamnterz, *Werner*.

Description.—Occurs in bright blue, short capillary crystals. Lustre glistening and silky.

Geognostic and Geographic Situations.—It is a rare mineral; its only known locality is the Bannat, where it is associated with green malachite and brown iron-ore.

Genus V.—EMERALD MALACHITE, or DIOPHASE.

Smaragd-Malachit, *Mohs*.

Rhombohedral. Colour lively emerald-green. Hardness = 5.0. Sp. gr. = 3.2,—3.4.

1. *Rhombohedral Emerald Malachite, or Dioptase*.

Rhomboedrischer Smaragd-Malachit, *Mohs*.—Kupferschmaragd, *Werner*.—Cuivre Dioptase, *Haüy*.

Specific Character.—Rhombohedral. Rhombohedron = $126^{\circ} 17'$. Cleavage rhombohedral. Streak green.

Description.—Colour emerald-green. Occurs regularly crystallized. Internally shining and pearly. Fracture conchoidal. Translucent, passing into semi-transparent.

Constituent Parts.—Oxide of copper 45.45, silica 43.18, water 11.36. *Vauquelin*.

Geognostic and Geographic Situations.—Is a very rare mineral, and has hitherto been found only in the land of the Kirgies in Tartary.

Genus VI.—GREEN MALACHITE.

Habronem-Malachit, *Mohs*.

Prismatic. Colour or streak bright green. Hardness = 2.5,—5. Sp. gr. = 3.5,—4.3.

1. *Prismatic Green Malachite, or Hydrous Phosphate of Copper*.

Prismatischer Habronem-Malachit, *Mohs*.—Phosphor Kupfererz, *Werner*.—Cuivre phosphaté, *Haüy*.

Specific Character.—Prismatic. Pyramid unknown.

Cleavage, $\text{Pr} + \infty$. Imperfect. (Fig. 30.) Streak emerald-green. Hardness = 5.0. Sp. gr. = 4.0,—4.3.

Description.—Colours emerald-green, externally with a blackish tarnish, or spotted black. Occurs regularly crystallized; in scopiform fibrous concretions; massive, reniform, botryoidal. Lustre ranges from shining to glimmering, and is resino-pearly. Fracture uneven. Opaque.

Constituent Parts.—Oxide of copper 62.85, phosphoric acid 21.68, water 15.45.

Geognostic and Geographic Situations.—Occurs at Virneberg, near Rheinbreitenbach, where it is disposed in veins in greywacke.

2. *Hemiprismatic Green Malachite, or Common Malachite*.

Hemiprismatischer Habronem-Malachit, *Mohs*.—Malachit, *Werner*.—Cuivre carbonaté vert, *Haüy*.

Specific Character.—Prismatic. Pyramid unknown.

Cleavage, $\text{Pr} \cdot \text{P} + \infty = 103^{\circ}$ (nearly.) (Fig. 33, 30.) Streak grass or apple green. Hardness = 3.5,—4.0. Sp. gr. = 3.6,—3.7.

Description.—Colour green. Occurs regularly crystallized; in distinct concretions, which are scopiform, fibrous, angulo-granular, and wedge-shaped; also massive, disseminated, tuberoso, stalactitic, reniform, botryoidal, fruticose, and cellular. Lustre ranges from shining to glimmering, and is silky. Fracture uneven, conchoidal, and even. Ranges from translucent to opaque.

Constituent Parts.—Copper 56.00, oxygen 14.00, carbonic acid 21.25, water 8.75. *Vauquelin*.

Geognostic and Geographic Situations.—Occurs in veins that traverse primitive, transition, and secondary rocks; also in beds, and disseminated through rocks of different kinds. The copper-mine of Sand-lodge, in Shetland, formerly afforded fine specimens of the fibrous varieties; and fine masses are sometimes found in the copper-mines of Cornwall.

3. *Prismatoidal Green Malachite or Muriate of Copper*.

Salkupferez, *Werner*.—Cuivre muriaté, *Haüy*.—Atacamite.

Specific Character.—Prismatic. $\text{Pr} = 107^{\circ} 10'$. $\text{P} + \infty = 67^{\circ} 15'$. Cleavage $\text{Pr} + \infty$, perfect. Streak apple-green. Hardness = 3.0,—3.5. Sp. gr. = 4.0,—4.3.

Description.—Colour green. Occurs regularly crystallized; in radiated and granular concretions; massive, disseminated, and in scaly particles. Lustre shining, glistening, and pearly. Translucent on the edges.

Constituent Parts.—Oxide of copper 76.6, muriatic acid 10.6, water 12.8.—*Proust*.

Geognostic and Geographic Situations.—Occurs in veins along with ores of copper in Chili, in the form of grains and scales in alluvial sand in the Desert of Atacama in Peru. Is also found in fissures of some Vesuvian lavas.

Order V.—MICA.

Cleavage monomous, very distinct. Hardness = 1.0,—4.5. Sp. gr. = 1.8,—3.4.

If metallic lustre, the sp. gr. is under 2.2. If no metallic lustre, the sp. gr. is above 2.2. If the streak is yellow, the sp. gr. is under 3.2. If the hardness is above 3.0, it is rhombohedral. If the sp. gr. is under 2.5, it is metallic.

Genus I.—COPPER MICA.

Streak green. Hardness = 2.0. Sp. gr. = 2.5,—2.6.

1. *Rhombohedral Copper Mica, or Micaceous Arseniate of Copper*.

Rhomboedrischer Euchlor-glimmer, *Mohs*.—Kupferglimmer, *Werner*.—Cuivre arseniaté, *Haüy*.

Specific Character.—Rhombohedral. Rhombohedron = $68^{\circ} 45'$. Cleavage $\text{R} - \infty$. Streak emerald, ... apple-green.

Description.—Colour green. Occurs regularly crystallized; in granular concretions; massive, and disseminated. Internally splendid and pearly. Fracture uneven. Translucent and transparent. Sectile.

Constituent Parts.—Oxide of copper 39.0, arsenic acid 43.0, water 17.0. *Vauquelin*.

Geognostic and Geographic Situations.—Occurs in the copper-mines of Cornwall.

Genus II.—URAN-MICA, or URANITE.

Streak green, ... yellow. Hardness = 2.0,—2.5. Sp. gr. = 3.0,—3.2.

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1. *Pyramidal Uran Mica.*

Pyramidaler Euchlor-glimmer, *Mohs.*—Uranglimmer, *Werner.*—Uran Oxyde, *Häuy.*

Specific Character.—Pyramidal. Pyramid = $95^{\circ} 13'$; $144^{\circ} 56'$. Cleavage, $P = \infty$.

Description.—Colours green and yellow. Occurs regularly crystallized; seldom massive, in scales, and in angular granular concretions. Lustre ranges from splendid to glistening, and is pearly. Transparent and translucent. Sectile. Not flexible. Easily frangible.

Constituent Parts.—Oxide of uran 59.37, phosphoric acid 14.63, water 14.90. *Berzelius.*

Geognostic and Geographic Situations.—Occurs in the copper and tin mines of Cornwall.

* *Uran Ochre.*—This is the yellow or reddish coloured, soft, earthy-looking, opaque mineral, occasionally associated with uran-mica, and also with uran-ore.

Genus III.—COBALT MICA, OR RED COBALT.

Kobalt-Glimmer, *Mohs.*

Prismatic. Colour and streak red. Folia flexible. Hardness = 2.5. Sp. gr. = 2.9,—3.1.

1. *Prismatic Cobalt Mica, or Red Cobalt.*

Prismatischer Kobalt-Glimmer, *Mohs.*—Rother Erd Kobalt, *Werner.*—Cobalt arseniaté, *Häuy.*

Specific Character.—Prismatic. Pyramid unknown.

Combination hemi-prismatic, $\frac{P}{2}$. Cleavage, $\bar{P}r + \infty$. (Fig. 29.) Streak red.

Description.—Colours red, rarely grey, green, and brown. Occurs regularly crystallized; in stellular and scopiform fibrous concretions; massive, disseminated, in crusts, reniform, and botryoidal. Lustre ranges from shining to dull, and is pearly and resinous. Fracture earthy and conchoidal. Sectile. Ranges from translucent to opaque.

Constituent Parts.—Oxide of cobalt 39.0, arsenic acid 37.0, water 22.0. *Bucholz.*

Geognostic and Geographic Situations.—Occurs in veins in primitive and secondary rocks, and is met with in the coal-field around Edinburgh, and in the old lead-mines of Tyndrum in Perthshire.

* *Cobalt Ochre.*—There are two kinds of this mineral.

1. *Black Cobalt Ochre.*—Schwarz Erd Kobolt, *Werner.* Colours black and occasionally brown. Occurs botryoidal, reniform, and in crusts. Lustre glimmering or dull. Fracture earthy and conchoidal. Opaque. Streak shining and resinous. Very soft, and sometimes friable.

It is a compound of black oxide of cobalt, with arsenic and oxide of iron.

It occurs at Alderley Edge, Cheshire, in red sandstone.

2. *Brown and Yellow Cobalt Ochre.*—These differ from the preceding principally in colour, the tints being yellow and brown.

Genus IV.—ANTIMONY MICA, OR WHITE ANTIMONY.

Antimon-Glimmer, *Mohs.*

Hardness = 2.5,—3.0. Sp. gr. = 5.5,—5.6.

1. *Prismatic White Antimony.*

Prismatisches Antimon-glimmer, *Mohs.*—Weiss-spiessglaserz, *Werner.*—Antimoine Oxyde, *Häuy.*

Specific Character.—Prismatic. $Pr - 1 = 70^{\circ} 32'$.

$(\bar{P} + \infty) = 136^{\circ} 58'$. Cleavage $(\bar{P}r + \infty)^2$, very perfect.

$\bar{P}r + \infty$. Streak white or grey.

Description.—Colours white and grey. Occurs regularly crystallized; in concretions which are scopiform and stellular radiated, and also granular. Lustre shining and pearly adamantine. Translucent.

Constituent Parts.—Oxide of antimony 86.0, oxide of antimony and iron 3.0, silica 8.0. *Vauquelin.*

Geognostic and Geographic Situations.—It occurs in veins in primitive rocks, along with galena and grey and red antimony, in Bohemia, France, and Hungary.

* *Antimony Ochre.*—Spiesglanzocker, *Werner.*

Colours yellow, brown, and green. Occurs massive, disseminated, and in crusts. Dull. Earthy. Opaque. Very soft.

It always occurs in veins along with grey, and occasionally with red antimony, as in Cornwall.

Genus V.—BLUE IRON, OR IRON MICA.

Eisen-Glimmer, *Mohs.*

Prismatic. Streak white, grey,...blue. Hardness = 2.0. Sp. gr. = 2.6,—2.7.

1. *Prismatic Blue Iron, or Iron Mica.*

Prismatisches Eisen Glimmer, *Mohs.*—Vivianit, *Werner.* Fer Phosphate, *Häuy.*

Specific Character.—Prismatic. Pyramid unknown.

Combination hemiprismatic, $\frac{P}{2} = 119^{\circ} 4'$. Cleavage $\bar{P}r + \infty$. (Fig. 29.)

Description.—Colours blue and green. Occurs regularly crystallized; in scopiform and promiscuous fibrous concretions; massive, disseminated, and thinly coating. Lustre ranges from splendid to dull, and is pearly, inclining to adamantine. Ranges from transparent to opaque.

It sometimes occurs in a friable, or loosely cohering state, and is then composed of dull dusty particles, forming *earthy blue iron.*

Constituent Parts.—Protoxide of iron 47.5, phosphoric acid 32.0, water 20.0. *Klaproth.*

Geognostic and Geographic Situations.—The crystallized varieties are found in Cornwall, those in fibrous concretions in Greenland, and the earthy and friable in our peat mosses.

Genus VI.—GRAPHITE.

Graphite Glimmer, *Mohs.*

Rhombohedral. Hardness = 1.0,—2.0. Sp. gr. = 1.8—2.1.

1. *Rhombohedral Graphite.*

Rhomboedrischer Graphit-glimmer, *Mohs.*—Graphit, *Werner.*—Graphite, *Häuy.*

Specific Character.—Rhombohedral. Rhombohedron unknown. Combination dirhombohedral. Cleavage $R = \infty$. Metallic aspect. Streak black.

Description.—Colour dark steel-grey, inclining to iron-black. Occurs regularly crystallized; in granular concretions; massive and disseminated. Lustre ranges from splendid to glimmering, and is metallic. Fracture scaly foliated, uneven, conchoidal, and slaty. Opaque. Sectile.

Constituent Parts.—Carbon 92.0, iron 8.0. *Vauquelin.*

Geognostic and Geographic Situations.—It occurs in beds and imbedded masses, in primitive, transition, and secondary rocks. In Scotland it occurs in gneiss, in Glen Strath-Farrar, in Inverness-shire; in the coal-formation in Ayrshire; and in England, in transition rocks near Borrowdale in Cumberland.

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logy

¹ This mineral, viewing it according to its whole physical characters, would be better placed in the genus Lead-Spar.

Genus VII.—TALC-MICA.

Talc-Glimmer, *Mohs*.

Rhombohedral. Prismatic. Streak white, grey, ... green. Hardness = 1.0, —2.5. Sp. gr. = 2.7, —3.0. If the streak is green, the sp. gr. = 2.8 and less.

1. *Prismatic Talc-Mica, or Talc.*Prismatischer Talc-glimmer, *Mohs*.

Specific Character.—Prismatic. $P + \infty = 120^\circ$. $P + \infty = 120^\circ$. Cleavage $P - \infty$. (Fig. 27.) Folia flexible. Streak white or green. Hardness = 1.0, —1.5. Sp. gr. = 2.7, —2.8.

Description.—Colours green, sometimes passing into greenish-black, also greenish-white, grey, and rarely blue. Occurs regularly crystallized; in granular, fibrous, and prismatic concretions; massive, disseminated, and in amygdaloidal pieces. Lustre ranges from splendid to dull, and is pearly or resinous. Fracture slaty, scaly foliated, earthy, and uneven. Ranges from translucent to opaque.

The dark green varieties, which are generally opaque, are named *chlorite*; of those the regularly crystallized are named *foliated chlorite*; the slaty, *chlorite slate*; the massive, scaly foliated, *common chlorite*; the massive in scaly foliated feebly adhering particles, *earthy chlorite*; and the dull earthy varieties met with in vesicular cavities in amygdaloid, *compact chlorite* or *green earth*. The white and paler green varieties are named *talc*; of these the most translucent, and possessing the highest degree of lustre, are denominated *common talc*; while the grey and green varieties, with slaty fracture and inferior lustre, and inferior translucency, are named *talc-slate* or *indurated talc*.

Constituent Parts.—1. *Foliated Talc*. Silica 62.0, magnesia 27.0, oxide of iron 3.5, alumina 1.5, water 6.0. *Vauquelin*.

2. *Chlorite Slate*. Silica 29.5, magnesia 21.4, oxide of iron, 23.4, alumina 15.6, water 7.4, lime 1.5. *Gruner*.

3. *Green Earth*. Silica 52.0, magnesia 6.0, oxide of iron 23.0, alumina 7.0, water 4.0, potash 7.5. *Vauquelin*.

Geognostic and Geographic Situations.—Occurs principally in primitive mountains, sometimes forming whole beds, as is the case with the varieties named chlorite-slate and talc-slate; other kinds, as common and earthy chlorite, occur disseminated, in veins, or dispersed through other minerals, as rock-crystal, felspar, &c., while the compact chlorite, or green earth, appears principally in secondary amygdaloid. The most beautiful variety of the species, the common talc, occurs chiefly in primitive rocks of limestone, mica-slate, &c. Examples of all the varieties are met with in the mountainous districts of Scotland and England.

1. *Native Magnesia, or Hydrate of Magnesia*.—Colours snow-white, greenish-white, and also grey. Occurs in prismatic concretions that point to the regular six-sided prism, also in granular concretions, and massive. Cleavage axotomous. Lustre shining and pearly. Semi-transparent in the mass, and transparent in single folia. Streak white, and affords on paper a polished pearly trace. Hardness = 1.0—1.5. Slightly elastic. Sp. gr. 2.13, *Bruce*; 2.336, *Brewster*. It is a pure hydrate of magnesia, the proportion of the constituent parts being, magnesia 70., water 30. Occurs in veins in serpentine, in the Shetland Islands, and in the serpentine of Portsoy, in Banffshire.

2. *Ophite, or Precious Serpentine*.—Colours pure leek-green, seldomer grass and oil green. Occurs massive and disseminated. Glistening and resinous lustre. Fracture flat conchoidal, inclining to splintery. Translucent, or translucent on the edges. Hardness 3.5. Sp. gr. = 2.5, —3.0.

3. *Nephrite*.—Colours green, grey, and white. Massive, and in rolled pieces. Dull or glimmering. Fracture splin-

tery. Strongly translucent. Difficultly frangible. Hardness = 7.0. Sp. gr. = 2.9, —3.1.

It occurs imbedded in various primitive rocks in Persia, Egypt, and Germany.

4. *Steatite or Soapstone*.—Colours white, red, and yellow, with frequent dendritic markings of black. Occurs massive, in crusts, and in false crystals. Fracture splintery and uneven. Dull or glimmering. Translucent on the edges. Sectile. Soft. Feels very greasy. It occurs principally in serpentine, as in that of the Shetland Islands and Cornwall.

N.B. The *Pimelite* of authors appears to be steatite coloured with nickel or chrome.

5. *Figurestone or Algalmatolite*.—Colours grey, green, white, red, and brown. Massive. Dull or glimmering. Fracture conchoidal, or splintery and slaty combined. Translucent. Resinous in streak. Feels rather greasy. The finest varieties are brought to Europe from China.

6. *Magnesite*.—Colours white, grey, and cream-yellow. Occurs massive, tuberoso, reniform, vesicular. Dull. Fracture conchoidal. Opaque. Hardness = 3.3. Sp. gr. = 2.881. Occurs in serpentine in Moravia, and in the Shetland Islands.

7. *Meerschaum*.—Colour white. Massive. Dull. Fracture earthy and conchoidal. Opaque or translucent on the edges. Very soft. Sectile. Adheres strongly to the tongue. Sp. gr. = 0.988, —1.279. Occurs in serpentine in Cornwall, Shetland Islands, &c.

8. *Lithomarge*.—Colours white, grey, blue, green, red, and yellow, and these are sometimes disposed in a veined, spotted, clouded, or striped manner. Occurs massive, disseminated, globular, and amygdaloid. Dull. Fracture earthy and flat conchoidal. Opaque. Shining in the streak. Soft. Sectile. Adheres strongly to the tongue. Feels fine and greasy. Sp. gr. —2.4. It occurs in trap, porphyry, and serpentine rocks, in Scotland and other countries.

9. *Mountain Soap*.—Colour blackish-brown. Massive. Dull. Fracture earthy. Opaque. Shining in the streak. Writes. Soft. Sectile. Adheres strongly to the tongue. Feels greasy. Occurs in secondary trap-rock, in the island of Skye.

10. *Bole*.—Colours brown, yellow, red, and black. Sometimes spotted, and dendritic. Massive and disseminated. Lustre glimmering. Fracture conchoidal. Feebly translucent. Soft. Feels greasy. Shining streak. Adheres to the tongue. Sp. gr. = 1.922. Occurs imbedded in secondary trap-rocks in Scotland.

2. *Rhombohedral Talc-Mica.*Rhombodrischer Talc-glimmer, *Mohs*.

Specific Character.—Regular six-sided prism, distinctly axotomous. Folia elastic. Streak white. Hardness = 2.0, —2.5. Sp. gr. = 2.8, —3.0.

Description.—Colours generally dark green and brown. Lustre pearly, inclining to metallic on the terminal faces of the prism. From transparent to opaque. Streak white or grey. Sectile. Folia very flexible and elastic.

Constituent Parts.—Silica 42.50, alumina 16.05, magnesia 25.97, potash 7.55, oxide of iron 4.93. *Rose*.

Geognostic and Geographic Situations.—It occurs in primitive districts, and in beautiful crystals in the ejected masses found on the Monte Somma. The Siberian and the Vesuvian varieties have been most noticed by mineralogists.

Observation.—The optical characters of the species are curious.

3. *Hemiprismatic Talc-Mica, or Common Mica.*Hemiprismatischer Talc-glimmer, *Mohs*.

Specific Character.—Oblique rhombic prism, with transverse sections of about 120° and 60° . Cleavage parallel to

Mineralogy. the base. Folia elastic. Streak white or grey. Hardness = 2.0,—2.5. Sp. gr. = 2.8,—3.0.

Description.—Colours white, grey, green, yellow, red, brown, and black. Lustre pearly. Transparent and translucent. Streak white or grey. Sectile. Flexible and elastic.

Constituent Parts.—1. From *Zinwald*. Silica 47.0, alumina 20.0, potash 14.50, oxide of iron 15.50, oxide of manganese 1.75, *Klaproth*. 2. *Red or Lepidolite Mica*. Silica 50.35, alumina 28.30, potash 9.04, oxide of manganese 1.23, fluoric acid and water 5.20, lithion 5.49, *Turner*. 3. *Zinnwald*. Silica 46.23, alumina 14.14, potash 4.90, oxide of iron 17.97, oxide of manganese 4.57, fluoric acid and water 3.73, lithion 4.21, *Gmelin*.

Geognostic and Geographic Situations.—Forms an essential constituent part of granite, gneiss, and mica-slate; abounds in many transition districts, and is frequent in sandstones of the secondary class. Hence its geographic distribution is universal.

Genus VIII.—PEARL-MICA.

Perl-Glimmer, *Mohs*.

Rhombohedral. Hardness = 3.5,—4.5. Sp. gr. = 3.0—3.1.

1. *Rhombohedral Pearl-Mica*.

Rhomboedrischer Perl-Glimmer, *Mohs*.

Specific Character.—Rhombohedral. Rhombohedron unknown. Combination dirhomboidal. Cleavage R—∞. Streak white or grey.

Description.—Colours white and grey. Occurs massive, in tables, and in granular concretions. Lustre splendid and pearly. Fracture foliated. Transparent to translucent. Streak white.

Constituent Parts.—Silica 37.0, alumina 40.5, lime 8.9, oxide of iron 4.50, natron 1.2, water 1.0. *Du Menil*.

Geognostic and Geographic Situations.—Occurs in beds, partly intermixed with mica and chlorite, at Sterzing, in the Tyrol.

Order VI.—SPAR.

Not metallic. Streak white, grey, brown, or blue. Hardness = 3.5,—7.0. Sp. gr. = 2.0,—3.7. If tessular, the sp. gr. = 3.0, and less. If rhombohedral, the sp. gr. = 2.2, or less, or the hardness = 6.0. If hardness = 4.0 and less, it is rhombohedral; or cleavage monotomous, and very distinct. If the hardness = 6.0, the lustre is pearly, the cleavage perfect, and sp. gr. less than 2.5, or more than 2.8. If sp. gr. = 3.3, the combination is hemi or tetarto prismatic; or the hardness = 6.0, but no adamantine lustre. If the sp. gr. = 2.4, and less, it is not without traces of form and cleavage.

Genus I.—SCHILLER-SPAR.

Schiller-spath, *Mohs*.

Prismatic. Cleavage monotomous, perfect. Metallic pearly lustre. Hardness = 3.5,—6.0. Sp. gr. = 2.6,—3.4.

1. *Diatomous*,¹ or *Common Schiller-Spar*.

Diatomer Schiller-spath, *Mohs*.—Schiller-stein, *Werner*.—Diallage Metalloide, *Haüy*.

Specific Character.—Prismatic. Pyramid unknown. Cleavage prismatoidal. Hardness = 3.5,—4.0. Sp. gr. = 2.6,—2.8.

Description.—Colours green, grey, and brown. Occurs in granular concretions; disseminated, and seldom massive. Lustre shining or splendid, and metallic pearly. Translucent on the edges, or opaque. Dull streak.

Constituent Parts.—Silica 43.90, magnesia 25.85, lime 2.64, oxide of iron 13.21, water 12.43. *Kohler*.

Geognostic and Geographic Situations.—Occurs imbedded in serpentine in the Shetland Islands, and in secondary trap-rocks in the middle district of Scotland.

2. *Hemiprismatic Schiller-Spar*, or *Bronzite*.

Hemiprismatischer Schiller-spath, *Mohs*.—Blättriger Anthophyllit, *Werner*.—Diallage Metalloide, *Haüy*.

Specific Character.—Hemiprismatic. Pyramid unknown.

Combination hemiprismatic. Cleavage $\frac{P}{2} \cdot \bar{Pr} + \infty$. Less perfect, $\frac{Pr}{2} \cdot \bar{Pr} + \infty$. (Fig. 29, 35, 28.) Lustre metallic-pearly. Hardness = 4.0,—5.0. Sp. gr. = 3.0,—3.3.

Description.—Colours brown and grey. Occurs in granular concretions. Lustre shining. Cleavage sometimes appears fibrous. Translucent on the edges. Streak white.

Constituent Parts.—Silica 60.0, magnesia 27.5, oxide of iron 10.5, water 0.5. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in serpentine in Shetland; in greenstone in the island of Skye, and near Portsoy; and in other parts of Scotland.

3. *Prismatoidal Schiller-Spar*, or *Hypersthene*.

Prismatoidischer Schiller-spath, *Mohs*.—Paulit, *Werner*.—Hypersthene, *Haüy*.

Specific Character.—Prismatic. $P + \infty = 93^\circ 0'$.

Cleavage $\bar{P} + \infty$; $\bar{Pr} + \infty$, perfect. $\bar{Pr} + \infty$, only traces. (Fig. 29, 30, 28.) Lustre metallic-pearly. Hardness = 6.0. Sp. gr. = 3.3,—3.4.

Description.—Colours greenish and greyish black; also copper-red and brown. Occurs in granular and lamellar concretions and massive. Lustre shining. Opaque or feebly translucent.

Constituent Parts.—Silica 54.25, magnesia 14.00, alumina 2.25, lime 1.50, oxide of iron 24.50, water 1.0. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in greenstone in the island of Skye; also in Banffshire and the Shetland Islands.

4. *Prismatic Schiller Spar*, or *Anthophyllite*.

Prismatischer Schiller-spath, *Mohs*.—Strahliger Anthophyllit, *Werner*.—Anthophyllite, *Haüy*.

Specific Character.—Prismatic. $P + \infty = 124^\circ 30'$.

Cleavage $\bar{Pr} + \infty$. Rather less perfect, $\bar{P} + \infty$. $\bar{Pr} + \infty$, least distinct. (Fig. 28, 30, 29.) Lustre metallic-pearly, inclining to vitreous. Hardness = 5.0,—5.5. Sp. gr. = 3.0,—3.3.

Description.—Colours yellowish grey and yellowish brown. Occurs crystallized in reed-like crystals; in scopiform and promiscuous radiated concretions; also massive. Translucent on the edges.

Constituent Parts.—Silica 56.0, alumina 3.0, magnesia 23.0, lime 2.0, oxide of iron 13.0, oxide of manganese 4.0. *Gmelin*.

Geognostic and Geographic Situations.—Occurs in primitive rocks near Drimnadrochit, in Inverness-shire.

Genus II.—KYANITE.

Disthen-spath, *Mohs*.

Prismatic. Cleavage prismatoidal, very distinct. Common pearly lustre. Hardness = 5.0,—7.0. Sp. gr. = 3.5,—3.7.

1. *Prismatic Kyanite*.

Disthen-spath, *Mohs*.—Kyanite and Rhatizit, *Werner*.—Disthene, *Haüy*.

Specific Character.—Prismatic. Pyramid unknown.

¹ From δια, through, and τμήνω, I cut; easily cleavable in one direction.

Mineralogy.

Combination tetarto-prismatic. Cleavage three faces, of varying degrees of perfection. Inclination of the most perfect to the less perfect = $100^{\circ} 50'$, to the least perfect = $106^{\circ} 15'$.

Description.—Colours blue and bluish green. Occurs regularly crystallized; in distinct concretions, which are granular and radiated, which latter are sometimes scopiform and stellular; also massive and disseminated. Lustre splendid and pearly. Translucent and transparent.

Constituent Parts.—Alumina 64.30, silica 34.33. *Arfwedson.*

Geognostic and Geographic Situations.—It occurs in primitive rocks in the Shetland Islands; also in Banffshire and Aberdeenshire.

Genus III.—SPODUMENE.

Hardness = 6.5,—7.0. Sp. gr. = 3.0,—3.1.

1. *Prismatic Spodumene.*

Spodumen, *Werner*.—Triphane, *Häuy*.

Specific Character.—Prismatic. $P + \infty = 93^{\circ} 0'$. Cleavage $P + \infty$. Somewhat more distinct, $Pr + \infty$. Not blue. (Fig. 30, 29.)

Description.—Colours greenish white and green. Occurs massive, and in large granular concretions. Lustre shining, glistening, and pearly. Fracture uneven. Translucent. Uncommonly easily frangible.

Constituent Parts.—Silica 66.49, alumina 25.30, lithion 8.85, oxide of iron 1.45. *Arfwedson.*

Geognostic and Geographic Situations.—Occurs in primitive rocks in Sweden and in Ireland.

Genus IV.—PREHNITE.

Axotomer Triphan-spath, *Mohs*.—Prehnite, *Werner* and *Häuy*.

Hardness = 6.0.—7.0. Sp. gr. = 2.8,—3.0. Not blue.

1. *Axotomous Prehnite.*

Specific Character.—Prismatic. $P + \infty = 99^{\circ} 30'$. Cleavage $P + \infty$. More distinct $P - \infty$. (Fig. 30, 27.)

Description.—Colours green, grey, and white. Occurs crystallized; in granular and in scopiform and stellular fibrous distinct concretions; massive and reniform. Lustre shining, glistening, and pearly. Fracture uneven. Ranges from transparent to translucent.

Constituent Parts.—Silica 43.60, alumina 23.00, lime 22.33, oxide of iron 2.00, water 6.40. *Thomson.*

Geognostic and Geographic Situations.—The more highly crystallized varieties have hitherto been found principally in primitive rocks, while the fibrous or less perfectly crystallized varieties occur principally in secondary trap-rocks. The secondary trap-rocks of Scotland afford many localities of this mineral.

Genus V.—DATOLITE.

Dystom-Spath, *Mohs*.

Prismatic. Internally, lustre resinous. Colour not blue. Hardness = 5.0,—5.5. Sp. gr. = 2.9,—3.0.

1. *Prismatic Datolite.*

Prismatischer Dystom-spath, *Mohs*.—Chaux Boratée Siliceuse, *Häuy*.

Specific Character.—Prismatic. Combination hemiprismatic. $\frac{P}{2} = 122^{\circ} 0'$. $P + \infty = 77^{\circ} 30'$. Cleavage $P + \infty$, less perfect $Pr + \infty$. (Fig. 30.)

Description.—Most frequent colours white and grey, seldom red, green, and yellow. Occurs regularly crystallized; also in granular, scopiform, and stellular, fibrous, and curved lamellar concretions; massive, reniform, and botryoidal. Lustre ranges from shining to dull, and is resinous or pearly.

Fracture conchoidal, uneven, and earthy. Ranges from transparent to opaque.

The reniform and botryoidal varieties in fibrous concretions are named *Botryolite*; the earthy-looking and botryoidal *Earthy Botryoidal Datolite*; all the others *Common Datolite*.

Constituent Parts.—Silica 38.51, lime 35.59, boracic acid 21.34, water 4.60. *Du Menil.*

Geognostic and Geographic Situations.—Occurs in beds of magnetic iron-ore, subordinate to gneiss, near Arendal in Norway, but rarely in other parts of Europe.

Genus VI.—ZEOLITE.

Kouphon-Spath, *Mohs*.

Tessular, rhombohedral, pyramidal, prismatic. Hardness = 3.5,—6.0. Sp. gr. = 2.0,—2.5. If pyramidal, is distinctly axotomous. If hardness = 6.9, is tessular.

1. *Trapezoidal Zeolite, or Leucite.*

Trapezoidaler Kuphon-spath, *Mohs*.—Leuzit, *Werner*.—Amphigène, *Häuy*.

Specific Character.—Tessular. Cleavage hexahedral, dodecahedral, imperfect. Hardness = 5.5,—6.0. Sp. gr. = 2.4,—2.5.

Description.—Colours white and grey. Occurs regularly crystallized; in granular concretions, and in roundish grains. Lustre shining or glistening, and vitreo-resinous. Fracture flat conchoidal. Ranges from transparent to opaque.

Constituent Parts.—Silica 54.0, alumina 23.0, potash 22.0. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in imbedded grains and crystals in older lavas, and associated with garnet, hornblende, quartz, glassy felspar, in the ejected masses of Monte Somma, and the extinct volcanoes on the Rhine, afford examples of leucite in both situations.

2. *Dodecahedral Zeolite, or Lapis Lazuli.*

Dodecaedrischer Kuphon-spath, *Mohs*.—Lazurstein, *Werner*. Lapis Lazuli, Sodalite, Hauyne, Spinellane, *Nosin*, of authors.

Specific Character.—Tessular. Cleavage dodecahedral, perfect. White, green, blue. Hardness = 5.5,—6.0. Sp. gr. = 2.25,—2.35.

Description.—Colours blue, green, white. Occurs in rhombohedral dodecahedrons, massive, and disseminated. Lustre shining and glistening, and vitreo-resinous. Fracture conchoidal or uneven. Streak white or grey. Translucent, or translucent on the edges.

Constituent Parts.—1. *Lapis Lazuli*. Silica 49.0, alumina 11.0, potash and soda 8.0, lime 16.0, oxide of iron 4.0, sulphuric acid 2.0, water a trace, *Gmelin*.—2. *Sodalite, from Greenland*. Silica 36.00, alumina 32.00, soda 25.00, muriatic acid 6.75, oxide of iron 0.25, *Eckeberg*.—3. *Hauyne*. Silica 33.48, alumina 18.87, potash 15.45, lime 12.00, oxide of iron 1.16, sulphuric acid 12.39, water 1.20, *Gmelin*.—4. *Spinellane*. Silica 43.0, alumina 29.5, soda 19.0, lime 1.5, oxide of iron 2.0, sulphuric acid 1.0, water 2.5, *Klaproth*.

Geognostic and Geographic Situations.—The Lapis Lazuli varieties of this species are found associated with primitive rocks in China, Persia, Siberia, and Bukhara. The Sodalite varieties occur in Greenland and Vesuvius; the Hauyne, in volcanic rocks in Vesuvius and on the banks of the Rhine; and the Nosin occurs at the Lake of Laach, near to Andernach.

3. *Hexahedral Zeolite, or Analcime.*

Hexaedrischer Kuphon-spath, *Mohs*.—Analcime, *Häuy*.—Kubizit, *Werner*.

Specific Character.—Tessular. Cleavage hexahedral imperfect. Hardness = 5.5. Sp. gr. = 2.0,—2.2.

Mineralogy.

Mineralogy.

Mineralogy.

Description.—Colours white, grey, reddish white. Occurs regularly crystallized; in angulo-granular concretions, and massive. Lustre shining, glistening, and vitreo-pearly. Fracture uneven, or conchoidal. Ranges from transparent to translucent.

Constituent Parts.—Silica 55.07, alumina 22.22, soda 13.71, water 8.22. *Connell.*

Geognostic and Geographic Situations.—Occurs in secondary greenstone rocks in Fifeshire, Salisbury Craig, near Edinburgh, and in the same rock in other parts of Scotland.

4. *Paratomous Zeolite, or Cross-stone.*

Paratomer Kuphon-spath, *Mohs.*—Kreutzstein, *Werner.*—Harmotome, *Häuy.*

Specific Character.—Prismatic. Pyramid unknown. Cleavage P . $Pr + \infty$. $Pr + \infty$. (Fig. 29, 28.) Hardness = 4.5. Sp. gr. = 2.3,—2.4.

Description.—Colours white and grey, sometimes also yellow and red. Most frequently in regular crystals, which are frequently twin-crystals; seldom massive. Lustre shining, glistening, and vitreo-pearly. Fracture conchoidal and uneven. Translucent.

Constituent Parts.—Silica 47.04, alumina 15.24, baryta 20.85, lime 0.10, potash 0.88, water 14.92. *Connell.*

Geognostic and Geographic Situations.—Occurs in galena veins in the mines of Strontian in Argyleshire, in secondary trap-rocks in Dumbartonshire, and other parts of Scotland.¹

5. *Rhombohedral Zeolite, or Chabasite.*

Rhomboedrischer Kuphon-Spath, *Mohs.*—Chabasie, *Häuy.*—Schabasit, *Werner.*

Specific Character.—Rhombohedral. Rhombohedron = $94^\circ 46'$. Cleavage rhombohedral. Hardness = 4.0,—4.5. Sp. gr. = 2.0,—2.1.

Description.—Colour white. Occurs regularly crystallized, seldom massive. Externally splendid, internally glistening and vitreous. Fracture conchoidal and uneven. Translucent.

Constituent Parts.—Kilmalcolm. Silica 50.14, alumina 17.48, lime 8.47, potash with soda 2.58, water 20.83. *Connell.*

Geognostic and Geographic Situations.—Occurs in various secondary trap-rocks, especially amygdaloid, and is not unfrequent in the trap-rocks of Scotland.

6. *Diatomous Zeolite, or Laumonite.*

Diatomer Kuphon-spath, *Mohs.*—Laumonite, *Werner,* *Häuy.*

Specific Character.—Prismatic. $P + \infty = 86^\circ 15'$. Combination hemiprismatic. Cleavage, $Pr + \infty$. More perfect, $Pr + \infty$. (Fig. 28, 29.) Hardness unknown. Sp. gr. = 2.3,—2.4.

Description.—Colour white. Occurs regularly crystallized, and in granular distinct concretions. Lustre shining, glistening, and pearly. When fresh is transparent; but on exposure to the atmosphere it very soon becomes opaque, and so soft as to yield to the pressure of the finger. Uncommonly easily frangible.

Constituent Parts.—Isle of Skye. Silica 52.04, alumina 21.14, lime 10.62, water 14.92. *Connell.*

Geognostic and Geographic Situations.—This mineral occurs in secondary trap-rocks in various parts of Scotland and Ireland.

7. *Prismatic Zeolite, or Mesotype.*

Prismatischer Kuphon-spath, *Mohs.*—Mesotype, *Häuy.*—Fibrous Zeolite, Natrolite.

Specific Character.—Prismatic. $P = 143^\circ 20'$; $142^\circ 40'$; $53^\circ 20'$. $P + \infty = 91^\circ 0'$. Cleavage $P + \infty$, very perfect. (Fig. 30.) Hardness = 5.0.—5.5. Sp. gr. = 2.0,—2.3.

Description.—Colours white, red, yellow, and yellowish-brown. Occurs regularly crystallized; in distinct concretions which are scopiform and stellular fibrous, granular, and curved lamellar; reniform, coralloidal, in plates and crusts. Lustre ranging from shining to dull, and is pearly. Fracture, in some varieties, coarse earthy. Ranges from nearly transparent to opaque.

The yellow and brown varieties, with striped colour delineations, and in which the fibrous and granular concretions are intersected by lamellar, are named *Natrolite*; those with earthy fracture and very soft, *Pearly zeolite*; while the other varieties are named *Fibrous zeolite*.

Constituent Parts.—Silica 54.46, alumina 19.70, soda 15.00, lime 1.61, water 9.83. Silica 47.21, alumina 25.60, soda 16.12, water 8.88, oxide of iron 1.35. Of these two analyses, the first is of common mesotype, the other of the natrolite-mesotype.

Geognostic and Geographic Situations.—Occurs principally in drusy cavities, or in veins in secondary trap-rocks in many places in Scotland. The natrolite is the rarest variety in Scotland.

Observation.—The natrolite variety is by some considered a distinct species.

8. *Prismatoidal Zeolite, or Stilbite.*

Prismatoidischer Kuphon-spath, *Mohs.*—Stilbite, *Häuy.*—Strahl-zeolith, *Werner.* Radiated zeolite.

Specific Character.—Prismatic. $P = 190^\circ 15'$; $114^\circ 0'$; $96^\circ 0'$. $P + \infty = 94^\circ 15'$. Cleavage, $Pr + \infty$, very perfect; traces according to $Pr + \infty$. (Fig. 29.) Hardness = 3.5,—4.0. Sp. gr. = 2.0,—2.2.

Description.—Colour white, sometimes grey, yellow, or red. Occurs regularly crystallized; in granular, and in scopiform, and stellular prismatic concretions; also massive and globular. Externally splendid. Internally shining and pearly. Alternates from transparent to translucent.

Constituent Parts.—Silica 52.50, alumina 17.07, lime 11.52, water 18.45. *Thomson.*

Geognostic and Geographic Situations.—Occurs in secondary trap-rocks in many districts in Scotland.

9. *Hemi-prismatic Zeolite, or Heulandite.*

Hemi-prismatischer Kuphon-spath, *Mohs.*—Blätter Zeolith, *Werner.*—Stilbite, *Häuy.* Foliated Zeolite.

Specific Character.—Hemiprismatic. Pyramid unknown. Combination, hemiprismatic $\frac{P}{2}$. Cleavage, $Pr + \infty$, very perfect. (Fig. 29.) Hardness = 3.5,—4.0. Sp. gr. = 2.0,—2.2.

Description.—Colours white, grey, red, and brown. Occurs regularly crystallized; in granular and lamellar distinct concretions. Fracture conchoidal. Externally, lustre splendid, shining, and vitreous; internally, shining and pearly. Ranges from transparent to translucent on the edges.

Constituent Parts.—Silica 59.95, alumina 16.87, potash 7.19, water 15.40. *Walmstadt.*

Geognostic and Geographic Situations.—Occurs in drusy cavities in secondary trap-rocks in the Hebrides and Mainland of Scotland.

10. *Pyramidal Zeolite, or Apophyllite.*

Pyramidaler Kuphon-spath, *Mohs.*—Albin Ichthyophthalm, *Werner.*—Mesotype epointée, *Häuy.*

¹ Another species is marked by authors under the name *Phillipsite*, which differs from *Crosstone* in having sp. gr. = 2.0,—2.2, and containing in place of baryta, lime and potash. Hence this mineral is by some named *Lime Crosstone*.

Mineralogy.

Specific Character.—Pyramidal. $P = 104^\circ 2'$; $122^\circ 0'$. Cleavage $P. = \infty$, very perfect. $[P + \infty]$ imperfect. Hardness = 4.5,—5.0. Sp. gr. = 2.2,—2.5.

Description.—Colour white. Occurs regularly crystallized; in straight and curved lamellar distinct concretions; massive and disseminated. Surface of the cleavage strongly iridescent. Externally splendid, the terminal planes of the prism pearly; internally glistening and vitreous. Ranges from transparent to translucent.

Constituent Parts.—From Iceland. Silica 50.76, lime 22.39, potash 4.18, fluoric acid trace, water 17.36. *Turner.*

Geognostic and Geographic Situations.—Occurs in secondary trap-rocks in the Hebrides and other parts of Scotland: the finest specimens are found in Iceland.

11. Macrotypous Zeolite, Brewsterite.

Specific Character.—Rhombohedral. $R = 79^\circ 29'$. Cleavage rhombohedral but imperfect. Hardness = 4.0. Sp. gr. 20,—2.2.

Constituent Parts.—Silica 58.66, alumina 17.49, Strontia 8.32, baryta 6.75, lime 1.34, oxide of iron, 0.29, water 12.58. *Connell.*

Geognostic and Geographic Situations.—Found in the lead-mines of Strontian, in cavities of trap at Giant's Causeway, and in the lead mines of St Turpet near Freyburg in the Brisgau.

Genus VI.—PETALITE.

Petalin-Spath, *Mohs.*

Prismatic. Hardness = 6.0,—6.5. Sp. g. = 2.4,—2.5.

1. Prismatic Petalite.

Prismatischer Petalin-spath, *Mohs.*

Specific Character.—Prismatic. Pyramid unknown. Cleavage $P + \infty = 95^\circ$ (nearly). More perfect, according to $\bar{P}r + \infty$.

Description.—Colours red and white. Occurs massive; internally glistening, shining, and nearly pearly. Translucent. Brittle, and rather easily frangible.

Constituent Parts.—Silica 79.21, alumina 17.22, lithia 5.76. *Arfwedson.*

Geognostic and Geographic Situations.—It has hitherto been found only in a mine of black iron-ore in the island of Uton in Sudermania, associated with spodumene, felspar, quartz, mica, and tourmaline.

Observations.—It was in this mineral Arfwedson discovered the alkali name lithia, since met with in other species.

Genus VII.—FELSPAR.

Rhombohedral pyramidal, prismatic. Hardness = 5.0,—6.0. Sp. gr. = 2.5,—2.8. If hardness = 5.5, and less, the form is pyramidal, but cleavage not axotomous.

1. Rhombohedral Felspar, or Nepheline.

Rhomboedrischer feldspath, *Mohs.*—Nepheline, *Häuy and Werner.*

Specific Character.—Rhombohedral. $R = 131^\circ 49'$. Combination di-rhombohedral. $2(R) = 152^\circ, 44'; 56^\circ 15'$. Cleavage, $R = \infty$. $R + \infty$. Hardness = 6.0. Sp. gr. = 2.5,—2.6.

Description.—Colours white and grey. Occurs regularly crystallized, and massive. Externally splendid, internally shining and vitreous. Fracture conchoidal. Translucent, passing into transparent.

Constituent Parts.—Silica 43.36, alumina 33.49, soda 13.36, potash 7.13. *Gmelin.*

Geognostic and Geographic Situations.—Occurs in drusy cavities in granular foliated limestone, with meionite, Vesuvian, pleonaste, rhombohedral garnet, mica, &c. in the ejected masses on Monte Somma, near Naples.

2. Prismatic Felspar, or Common Felspar, Potash Felspar.

Prismatischer Feldspath, *Mohs.*—Orthoclase, *Breithaupt.* Ice-Spar.—Amazonstone.—Potash Felspar.

Prismatic. Pyramid = $134^\circ 26'; 126^\circ 52'; 72^\circ 32'$.

$P + \infty = 81^\circ 47'$. Combination $\frac{P}{2} = 126^\circ 52'$. Cleavage

$\frac{Pr}{2}$. $Pr + \infty$. Both very perfect. Less distinct ($\bar{P}r + \infty$)³ = 120° . Sometimes only one of the faces. (Fig. 44.) Hardness = 6.0. Sp. gr. = 2.5,—2.8.

Description.—Colours white, grey, green, blue, red, and brown; and sometimes with pearly opalescence, and beautiful changeability of colour. Occurs regularly crystallized; in distinct concretions, which are angulo-granular and lamellar; massive and disseminated. Lustre ranges from splendid to glistening, and even to dull, and is vitreopearly, or vitreous. Fracture conchoidal, splintery, slaty, and earthy. Ranges from transparent to opaque.

The transparent and translucent white-coloured varieties, with the silvery or pearly opalescence, are named *adularia*, also *moonstone*; the white and grey transparent varieties usually in small crystals, which are traversed by numerous rents, are named *glassy felspar*;¹ the translucent varieties, with various shades of colour, such as white and red, are the most abundant, and hence are named *common felspar*; the blue and green varieties are named *amazonstone*; the dark-grey varieties, with the beautiful changeability of colour, from Frederickswarn, are named *Norwegian Labrador felspar*; the feebly translucent compact varieties, with splintery fracture, are named *compact felspar*; the slaty varieties, with feeble lustre and translucency, are named *slaty felspar* or *clinkstone*; the varieties, in a comparatively loose state of aggregation, and without lustre and transparency, according to the degrees of compactness, are named *porcelain earth*, *earthy felspar*, and *claystone*.

Geognostic and Geographic Situations.—Potash-felspar is one of the most abundant minerals in nature, as it occurs in most of the principal rocks in primitive and transition mountains. It abounds in the alpine districts of Scotland, England, and Ireland, in granite, syenite, gneiss, porphyry, and quartz rocks.

3. Tetarto-prismatic Felspar, Albite or Soda Felspar.

Cleavelandite. Tetartin, *Breithaupt.*—Soda felspar.—Some so called Adularias.

Specific Character.—Inclination of $\frac{Pr}{2}$ to $Pr + \infty = 93^\circ 20'$; of $r \frac{(P + \infty)^2}{2}$ to $1 \frac{(P + \infty)^2}{2} = 121^\circ 38'$. Combina-

tion tetarto-prismatic. Cleavage $\frac{\bar{P}r}{2}$, $\bar{P}r + \infty$, very perfect. Hardness = 6.0. Sp. gr. = 2.6,—2.68.

Description.—Colour generally white, sometimes grey, green, or red. Massive, and disseminated. Lustre upon faces of cleavage pearly, in other directions vitreous. Transparent, but more frequently translucent on the edges. Streak white. Brittle.

Constituent Parts.—From Chesterfield in America. Silica 70.68, alumina 19.80, soda 9.06, lime 0.23, *Stromeyer.* From Arendal. Silica 68.84, alumina 20.53, soda 9.12. Lime a trace. *Rose.*

Geognostic and Geographic Situations.—Forms a constituent part of the greenstone rocks so abundant around Edinburgh. Is associated with epidote and garnet in gneiss rocks at Arendal in Norway. Transparent crystals are found along with pearl-spar in the Tyrol. In the granite

¹ Glassy Felspar has been lately described as a distinct species under the name *Ryakolite*.

Mineralogy. of the Mourne mountains in Ireland it is associated with common felspar.

4. *Polychromatic or Labrador Felspar. Lime Felspar.*

Polychromatischer feldspath, *Mohs.*

Specific Character.—Inclination of $\frac{\bar{P}r}{2}$ to $\bar{P}r + \infty = 93^\circ 20'$. Combination tetarto-prismatic. Cleavage $\frac{\bar{P}r}{2}$, very perfect; $\bar{P} + \infty$, less perfect. Hardness = 6.0. Sp. gr. 2.69,—2.76.

Description.—Colour grey, with splendid changeability of colour, exhibiting patches of brilliant blue, green, yellow, red, and pear-grey colours. Occurs massive and disseminated. Lustre pearly on the perfect cleavage faces. The beautiful changeability of colour seen to greatest advantage upon particular faces of the mass. Translucent, or nearly opaque.

Constituent Parts.—Silica 55.75, alumina 26.50, lime 11.0, soda 4.0, oxide of iron 1.25, water 0.50.

Geognostic and Geographic Situations.—This beautiful mineral was first noticed on the coast of Labrador as a constituent part of syenite, hence its name Labradorite. Sir Charles Giesecke found it also in Greenland. It has also been met with in different parts of Europe.

5. *Pyramidal Felspar, or Scapolite, Meionite.*

Pyramidaler Feldspath, *Mohs.*—Meionite Scapolith, Schmelzstein. *Werner.*—Paranthine, Meionite, Wernerite, Dipyre, *Häuy.*

Specific Character.—Pyramidal. Pyramid = $136^\circ 7'$; $63^\circ 48'$. Cleavage $P - \infty$. More perfect, $P + \infty$. [$P + \infty$]. Hardness = 5.0,—5.5. Sp. gr. = 2.5,—2.8.

Description.—Colours white, grey, green, red, and black. Occurs regularly crystallized; in distinct concretions, which are scopiform, fibrous, or radiated, and angulo-granular; massive and disseminated. Lustre ranges from splendid to glimmering, and is pearly, resino-vitreous, and resino-pearly. Fracture conchoidal, uneven. Ranges from transparent to opaque.

The white and more transparent and highly crystallized varieties are named *Meionite*, while the others have received the names *Scapolite*, *Paranthine*, *Wernerite*, *Dipyre*, and *Schmelzstein*.

Constituent Parts.—1. *Meionite.* Silica 45.53, alumina 32.73, lime 24.25, potash and soda 1.82, protoxide of iron 0.18. *Stomeyer.*—2. *Scapolite.* Silica 43.83, alumina 35.43, lime 18.96, water 0.03. *Nordenskiöld.*—3. *Wernerite.* Silica 50.25, alumina 30.00, lime 10.45, potash and soda 2.00, protoxide of iron 4.45, water 2.85. *John.*—4. *Dipyre.* Silica 60.0, alumina 24.0, lime 10.0, water 2.0. *Vauquelin.*

Geognostic and Geographic Situations.—The *meionite* varieties are found in drusy cavities in granular foliated limestone, along with nepheline, augite, mica, pleonaste, garnet, and calcareous spar, on Monte Somma, near Naples; *scapolite* and *Wernerite* varieties occur in beds of magnetic ironstone and iron-pyrites, in gneiss, along with quartz, felspar, mica, hornblende, epidote, garnet, augite, &c. at Arendal in Norway; the *paranthine* varieties in limestone quarries in Wermeland; the *dipyre* varieties in the torrent of Mauleon in the Western Pyrenees.

Observations.—Breithaupt describes a felspar under the name *Peregrine*, nearly allied to albite, but distinguished from it by its inferior specific gravity, it being only 2.54,—2.56; and Rose describes another species under the name anorthite, but the limited nature of this article prevents us noticing them more particularly.

Genus VIII.—AUGITE.

Prismatic. Lustre not metallic-pearly. Hardness = 4.5,—7.0. Sp. gr. = 2.7,—3.5. If the hardness is above 6.0,

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the sp. gr. = 3.2, and more. If the sp. gr. is under 3.2, the cleavage is very perfect, and, in obliquely intersecting directions, parallel to the axis.

1. *Paratomous Augite.*

Paratomer Augit, *Mohs.*—Augit, *Werner.*—Pyroxene Häuy.

Specific Character.—Prismatic. Pyramid = $152^\circ 12'$; 120° ; $61^\circ 2'$. $P + \infty = 51^\circ 19'$. Combination hemiprismatic. $\frac{P}{2} = 120^\circ$. Cleavage, $(\bar{P}r + \infty)^3 = 87^\circ 42'$,

$\bar{P}r + \infty$. $\bar{P}r + \infty$. Sometimes $\frac{\bar{P}}{2}$. (Fig. 32, 29, 28, 38.)

Hardness = 5.0,—6.0. Sp. gr. = 3.2,—3.5.

Description.—Colours green, black, and brown; also grey and white. Occurs regularly crystallized; in granular and fibrous concretions; massive and disseminated. Lustre ranges from splendid to glimmering, and is vitreo-resinous, resino-pearly, and resinous. Fracture conchoidal and uneven. Ranges from transparent to translucent on the edges.

Those varieties in which the colours are white and pale green, generally crystallized, with a vitreous external, and pearly internal lustre, and translucent, are named *Diopside*, *Musite*, *Alalite*, and by some *Baikalite*; those, again, in which the colours are darker green and muddy grey, less frequently crystallized, but disposed in straight, lamellar, and granular concretions, with a shining, vitreous, or pearly lustre, and translucent on the edges, are named *Sahlite*, *Pyrogome*, *Fassaite*, *Malacolite*, and by some *Baikalite*; other varieties, in which the colours are black and dark green, with conchoidal and uneven fracture, resinous lustre, and opaque or faintly translucent on the edges, are named *Conchoidal Augite* and *Common Augite*; those varieties in which the colours are principally leek-green and greenish-black, generally in loosely aggregated angulo-granular concretions, with a shining vitreo-resinous lustre, uneven fracture, and ranging from translucent to opaque, are named *Coccolite* and *Granular Augite*; and, lastly, the fibrous varieties have been described as *Amianthus*.

Constituent Parts.—1. *White Varieties.* Silica 54.83, lime 24.76, magnesia 18.55, alumina 0.28, protoxide of iron 0.99. *Bonsdorf.*—2. *Green Varieties.* Silica 54.08, lime 23.47, magnesia 11.49, protoxide of iron 10.02, manganese 0.51. *Rose.*—3. *Black Varieties.* Silica 53.36, lime 22.19, magnesia 4.19, protoxide of iron 17.38, oxide of manganese 0.09. *Rose.*

Geognostic and Geographic Situations.—The diopside varieties are found imbedded in serpentine, and associated with magnetic iron-ore in Piedmont: the sahlite in beds of primitive trap, limestone, and magnetic iron-ore, subordinate to gneiss and mica-slate in Scotland, Ireland, and Scandinavia; the conchoidal augite and common augite occur principally in secondary trap-rocks; and the coccolite and granular augite in the iron mines of Arendal, in Norway, in gneiss.

2. *Hemiprismatic Augite, or Hornblende.*

Hemi-prismatischer Augit-spath, *Mohs.*—Hornblende, &c., *Werner.*—Amphibole, *Häuy.*

Specific Character.—Prismatic. Pyramid = $151^\circ 8'$; $148^\circ 39'$; $42^\circ 22'$. $P + \infty = 87^\circ 11'$. Combination hemiprismatic, $\frac{P}{2} = 148^\circ 39'$. Cleavage, $(\bar{P}r + \infty)^3 =$

$124^\circ 34'$. Less distinct, $\bar{P}r + \infty$. $\bar{P}r + \infty$. (Fig. 32, 29, 28.) Hardness = 5.0,—6.0. Sp. gr. = 2.7,—3.2.

Description.—Colours green, white, black, grey, blue, and brown. Occurs regularly crystallized; in fibrous, radiated, and granular distinct concretions. Lustre ranges from splendid to feebly glimmering, and lustre vitreo-

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pearly, pearly, or vitreous, and vitreo-resinous. Fracture conchoidal, uneven, and slaty. Alternates from transparent to opaque.

The varieties with dark green and black colours, in granular and fibrous concretions, and in which the lustre ranges from splendid to shining, and is pearly or pearly-vitreous, and the transparency from transparent to translucent on the edges, are named *Hornblende* and *Carinthine*; the varieties with light green, and also greenish-grey, and sometimes brown and yellow colours, rarely crystallized (and then generally in reed-like crystals), more frequently massive, and in radiated, fibrous, and granular concretions, with a pearly or vitreous, splendid, shining, or glistening lustre, and transparency varying from transparent to opaque, are named *Actynolite* and *Calamite*; the white and blue varieties, disposed in fibrous, radiated, and granular concretions, with a lustre which is shining, or glistening and pearly, or vitreo-pearly, and ranging from translucent to translucent on the edges, are named *Tremolite*; other varieties, in which the colours are white, green, yellow, blue, and brown, and disposed in flexible, shining, silky, fibrous concretions, are named *Flexible Asbestos* or *Amianthus*; others, which are of a white colour, or grey colour, and disposed in minute promiscuous fibrous concretions, and so light as to swim in masses in water, are named *Mountain Cork*; those in which the colours are generally green, and disposed in straight, shining, pearly, rigid, fibrous concretions, are named *Rigid or Common Asbestos*; and, lastly, those varieties in which the colour is wood-brown, and in general aspect much resembling fossil-wood, are named *Rockwood* or *Ligneous Asbestos*.

Constituent Parts.—*White.* Silica 60.31, magnesia 24.23, lime 13.66, alumina 0.26, protoxide of iron 0.15, fluoric acid 0.94, water and foreign matter 0.10. *Bonsdorf.*—*Green.* Silica 46.26, magnesia 19.03, lime 13.96, alumina 14.48, protoxide of iron 3.43, protoxide of manganese 0.36, fluoric acid 1.60, water, &c. 1.04. *Bonsdorf.*—*Black.* Silica 45.69, magnesia 18.79, lime 13.85, alumina 1.18, protoxide of iron 7.32, fluoric acid 1.50. *Bonsdorf.*

Geognostic and Geographic Situations.—The *hornblende* varieties abound in primitive and transition rocks, and are also met with in those of the secondary class; those named *actynolite* and *tremolite* scarcely occur in secondary rocks, being confined principally to those of the primitive class; while the *asbestine* varieties are principally met with in the serpentine rocks of primitive and transition mountains. Numerous localities of this species occur in Scotland, England, and Ireland.

2. Prismatoidal Augite, or Epidote.

Prismatoidischer Augit-spath, *Mohs.*—Epidote, *Haiiy.*

Specific Character.—Prismatic. Pyramid unknown. Combination hemiprismatic. Cleavage, two faces, of which one is more distinct than the other. Incidence = $114^{\circ} 37'$. Hardness = 6.0,—7.0. Sp. gr. = 3.2,—3.5.

Description.—Colours green and grey. Occurs regularly crystallized; in granular, fibrous, and prismatic concretions. Lustre ranges from splendid to glimmering, and is resino-pearly. Fracture conchoidal, uneven, splintery, and sometimes nearly earthy. Ranges from transparent to translucent on the edges. Brittle, and easily frangible.

The green varieties are named simply *epidote*, or *pistacite*; while the grey and less perfectly crystallized varieties are named *zoisite*.

Constituent Parts.—1. *Pistacite, or Green Varieties.* silica 37.0, alumina 27.0, lime 14.0, oxide of iron 17.0, oxide of manganese 1.5. *Descostes.*—2. *Grey Variety, or Zoisite.* Silica 45.0, alumina 29.0 lime 21.0, oxide of iron 3.0. *Klaproth.*

Geognostic and Geographic Situations.—It occurs principally in primitive rocks, such as gneiss, mica-slate, syenite,

&c. Inverness-shire, Ross-shire, the Shetland Islands, and other parts of Scotland, afford many varieties.

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4. Prismatic Augite, or Wollastonite.

Prismatischer Augit-spath, *Mohs.*—Schaalstein, *Werner.*—Spath en Tables, *Haiiy.* Table Spar.

Specific Character.—Prismatic. Pyramid unknown.

Cleavage, $P + \infty = 105^{\circ}$ (nearly). $Pr + \infty$. $Pr + \infty$. Sp. gr. = 2.7,—2.9. Hardness = 4.5,—5.0.

Description.—Colour white. Occurs in granular and lamellar concretions; also massive and disseminated. Lustre ranges from shining to glistening, and is pearly-vitreous. Fracture splintery. Translucent. Brittle.

Constituent Parts.—Silica 51.45, lime 47.41, oxide of iron 0.40. *Stromeyer.*

Geognostic and Geographic Situations.—Occurs in primitive rocks in the Bannat, in Norway, Finland, and in rocks of the same description in the island of Ceylon.

Genus IX.—AZURE-SPAR.

Colour blue. Prismatic. Hardness = 5.0,—6.0. Sp. gr. = 2.8,—3.1.

1. Prismatic Azure-Spar.

Lazulit, *Werner.*—Lazulite, *Haiiy.*—Prismatischer Lazur-spath, *Mohs.*

Specific Character.—Prismatic. Cleavage $P + \infty$ (imperfect). Colour lively. Hardness = 5.0,—5.5. Sp. gr. = 3.0,—3.1.

Description.—Colour blue. Occurs massive. Fracture uneven. Opaque. Very feebly translucent on the edges. Easily frangible.

Constituent Parts.—Phosphate of lime 41.81, alumina 35.73, magnesia 9.34, silica 2.10, protoxide of iron 2.64, water 6.06. *Fuchs.*

Geognostic and Geographic Situations.—Occurs imbedded in quartz in the district of Vorau, in Stiria.

2. Prismatoidal Azure-Spar, or Blue Spar.

Blauspath, *Werner.*—Feldspath, *Haiiy.*

Specific Character.—Prismatic. Cleavage prismatoidal, imperfect. Colour pale. Hardness = 5.5,—6.0. Sp. gr. = 3.0,—3.1.

Description.—Colour blue. Occurs massive and disseminated. Lustre glistening. Fracture splintery. Feebly translucent. Yields a greyish-white streak.

Constituent Parts.—Alumina 34.50, phosphoric acid 43.32, magnesia 13.56, silica 6.50, oxide of iron 0.80, water 0.50. *Brandes.*

Geognostic and Geographic Situations.—Occurs in primitive rocks at Krieglach in Stiria.

3. Uncleavable Azure-Spar, or Calaité—Mineral Turquois.

Specific Character.—No cleavage. Hardness = 6.0. Sp. gr. = 2.8,—3.0.

Description.—Massive. Disseminated. Blue. Streak white. Feebly translucent on the edges, or opaque. Internally dull. Fracture conchoidal.

Constituent Parts.—According to Berzelius it consists of phosphate of alumina and phosphate of lime with silica, the oxides of iron and copper, and a little water. John, the Russian chemist, on the contrary, found it composed of alumina 73.0; copper 4.5; oxide of iron 4.0; water 18.0.

Geognostic and Geographic Situations.—This beautiful mineral occurs in small veins in a slate-clay in Persia, where it is much prized as an ornamental stone.

Observation.—The Bone-Turquois is not true Calaité, but bone coloured with oxide of copper.

Order VII.—GEM.

Not metallic. Streak white or grey. Hardness = 5.5.

Mineralogy. —10.0. Sp. gr. = 1.9,—4.7. If hardness = 6.0, and less, the sp. gr. = 2.4, and less, and no traces of form or cleavage. If sp. gr. is less than 3.8, there is no pearly lustre.

Genus I.—ANDALUSITE.

Prismatic. Cleavage, not prismatic. Hardness = 7.5. Sp. gr. = 3.0,—3.2.

1. *Prismatic Andalusite.*

Prismatischer Andalusit, *Mohs.*—Andalusit, *Werner.*—Feldspath apyre, *Haüy.*

Specific Character.—Prismatic. Pyramid unknown. Cleavage, $P + \infty$. $Pr + \infty$. $Pr + \infty$. (Fig. 30, 29, 28.)

Description.—Colours red and grey. Occurs regularly crystallized and massive. Lustre shining, glistening, and vitreous. Fracture uneven. Feebly translucent.

Constituent Parts.—Alumina 60.5, silica 36.5, oxide of iron 4.0. *Bucholz.*—Alumina 52.0, silica 28.0, oxide of iron 2.0, potash 8.0. *Vauquelin.*

Geognostic and Geographic Situations.—Occurs in gneiss in the Shetland Islands, and in slate rocks in Banffshire.

* *Fibrolite.*—Bournon.

Prismatic. $P + \infty = 100^\circ$. Cleavage imperfect. Hardness more considerable than quartz, and sp. gr. = 3.214.

Constituent Parts.—According to Chenevix consists of silica 33.0, alumina 46.0, oxide of iron 13.0. Occurs in the Carnatic and in China.

* *Chiastolite.* *HolSPATH, Werner.*—Macle, *Haüy.*

Prismatic. $P + \infty = 84^\circ 48'$. $Pr = 120$ nearly. Cleavage, $P + \infty$. $Pr + \infty$. $Pr + \infty$. All of them imperfect. Hardness = 5,—5.5. Sp. gr. = 2.9,—3.0.

Constituent Parts.—Silica 68.49, alumina 30.17, magnesia 4.12, oxide of iron 2.7, water 0.27.—*Landgrabe.*

Geognostic and Geographic Situations.—Occurs in clay-slate near Keswick in Cumberland, and near Bala-hulish in Argyllshire.

Genus II.—CORUNDUM.

Tessular, rhombohedral, prismatic. Hardness = 8.0.—9.0. Sp. gr. = 3.5,—4.3. If prismatic, the sp. gr. = 3.7, and more, and hardness = 8.5. If colour red, and sp. gr. = 3.7, and more, the hardness = 9.0.

1. *Dodecahedral Corundum, or Spinel.*

Dodecaedrischer Corund, *Mohs.*—Spinel and Zeilanit, *Werner.*—Spinelle and Pleonaste, *Haüy.*

Specific Character.—Tessular. Cleavage, octahedral, but obtained with difficulty. Hardness = 8.0. Sp. gr. = 3.5,—3.8.

Description.—Colours red, and sometimes green, black, blue, yellow, brown, and white. Occurs regularly crystallized. Lustre splendid and vitreous. Fracture conchoidal. Ranges from transparent to translucent on the edges.

The dark green and black varieties, which are only translucent on the edges, are named *ceylanite*; the other varieties *spinel* or *spinel-ruby*.

Constituent Parts.—*Red Spinel.* Alumina 74.50, silica 15.56, magnesia 8.25, oxide of iron 1.56, lime 0.75. *Klaproth.*

Geognostic and Geographic Situations.—The *ceylanite* varieties occur in the sand of rivers in Ceylon; the others also in Ceylon, Pegu, and other countries.

2. *Octahedral Corundum or Automolite.*

Octaedrischer Corund, *Mohs.*—Automalite, *Werner.*—Gahnite. Spinelle Zincifere, *Haüy.*

Specific Character.—Tessular. Cleavage, octahedral, and easily obtained. Hardness = 8. Sp. gr. = 4.1,—4.3.

Description.—Colour muddy dark-blue, passing into

blackish-green. Occurs regularly crystallized. External lustre pearly, inclining to semimetallic, internally shining and resinous. Fracture conchoidal. Opaque or faintly translucent on the edges.

Constituent Parts.—Alumina 60.00, oxide of zinc 24.25, oxide of iron 9.25, silica 4.75. *Eckeberg.*

Geognostic and Geographic Situations.—Occurs imbedded in talc, and associated with lead-glance at Fahlun in Sweden, also in New Jersey in the United States of America.

3. *Rhombohedral Corundum. Sapphire. Oriental Ruby, &c.*

Rhomboedrischer Corund, *Mohs.*

Specific Character.—Rhombohedral. Rhombohedron = $86^\circ 6'$. Cleavage $R = \infty$. More perfect R . Hardness = 9.0. Sp. gr. = 3.0,—4.05.

Description.—Colours blue, red, grey, white, green, yellow, brown, and black. Occurs regularly crystallized, also massive. Lustre ranges from splendid to glimmering, and vitreous, or vitreous sometimes inclining to adamantine. Fracture conchoidal and uneven. Ranges from transparent to feebly translucent on the edges.

The transparent blue varieties are named *sapphire*; the transparent red varieties, *oriental ruby*; the massive, nearly opaque, grey and blackish varieties, *emery*; the translucent, massive, and crystallized varieties, *common corundum*; and the brown faintly translucent varieties, *adamantine spar*.

Constituent Parts.—*Sapphire.* Alumina 98.5, oxide of iron 1.0, lime 0.5. *Klaproth.*—*Emery.* Alumina 86.0, silica 3.0, oxide of iron 4.0. *Tennant.*

Geognostic and Geographic Situations.—The finest sapphires and oriental rubies are found in alluvial soil in Ceylon and Pegu, and other eastern countries; the emery occurs in primitive talc-slate in Saxony; the common corundum and adamantine spar in granite, syenite, and other similar rocks in India and China.

4. *Prismatic Corundum, or Chrysoberyl.*

Prismatischer Corund, *Mohs.*—Krysoberyll, *Werner.*—Cymophane, *Haüy.*

Specific Character.—Prismatic. Pyramid = $139^\circ 53'$; $86^\circ 16'$; $107^\circ 29'$. $P + \infty = 128^\circ 35'$. Cleavage = $Pr + \infty$. Less perfect $Pr + \infty$. (Fig. 29, 28.) Hardness = 8.5. Sp. gr. = 3.65,—3.8.

Description.—Colour green, and often exhibits a milk-white opalescence. Occurs regularly crystallized, and in blunt edged pieces. Lustre splendid and resino-vitreous. Fracture conchoidal. Semi-transparent and transparent.

Constituent Parts.—Alumina 76.75, glucina 17.79, protoxide of iron 4.49, moisture 0.48. *Thomson.*

Geognostic and Geographic Situations.—Occurs imbedded in granite veins in America, in alluvial soil in Ceylon, and apparently in the granite of Aberdeen.

Genus III.—DIAMOND.

Tessular. Hardness = 10. Sp. gr. = 3.4,—3.6.

1. *Octahedral Diamond.*

Specific Character.—Tessular. Cleavage octahedral.

Description.—Its colours are more numerous than in most other minerals, and of the various tints the grey and white are the most frequent; it exhibits also beautiful red, yellow, and blue varieties. Occurs regularly crystallized, and in roundish grains. The lustre splendid and adamantine. Fracture conchoidal. Transparent and semi-transparent.

Constituent Parts.—Consists of pure carbon, and is completely volatilized at a temperature of 14° , Wedgewood, affording with oxygen, carbonic acid gas.

Geognostic and Geographic Situations.—It has hitherto been found principally loose in alluvial soil, in the warmer regions of the earth, as Brazil, Borneo, the Peninsula of

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Genus IV.—TOPAZ.

Prismatic. Cleavage axotomous. Hardness = 8. Sp. gr. = 3.4,—3.6.

1. Prismatic Topaz.

Prismatischer Topaz, *Mohs.*—Topaz. Physalit. Piknit, *Werner.*—Silice Fluatée Alumineuse, *Haüy.*

Specific Character.—Prismatic. Pyramid = $141^{\circ} 7'$; $101^{\circ} 52'$; $90^{\circ} 55'$. $P + \infty = 124^{\circ} 19'$. Combination, sometimes with different planes on opposite ends. Cleavage, $P + \infty$. (Fig. 27.)

Description.—Colours yellow, green, blue, red, grey, white. Occurs regularly crystallized; also in prismatic and granular concretions, and massive. Lustre ranges from splendid to glistening, and is vitreous and resinous. Fracture conchoidal and uneven. Ranges from transparent to translucent on the edges. Easily and uncommonly easily frangible.

The highly crystallized and transparent varieties are named *precious topaz*; those in prismatic distinct concretions, with a slight degree of translucency on the edges, and which are uncommonly easily frangible, *schorlous topaz*; and those in coarse granular concretions, with a low degree of lustre, and feeble translucency on the edges, *physalite*.

Constituent Parts.—1. *Precious Topaz.* Alumina 57.45, silica 34.24, fluoric acid 7.75. *Berzelius.*—2. *Schorlous Topaz.* Alumina 51.00, silica 38.43, fluoric acid 8.84. *Berzelius.*—3. *Physalite.* Alumina 57.74, silica 34.36, fluoric acid 7.77. *Berzelius.*

Geognostic and Geographic Situations.—Precious topaz occurs in alluvial soil in the upper parts of Aberdeenshire, in primitive rocks in Cornwall, in granite in the Mourne Mountains in Ireland; schorlous topaz is said also to occur in Aberdeenshire; and the physalite in granite, at Finbo in Sweden, and at Altenberg in Saxony. The Uralian and Altain Mountains in Asiatic Russia, and those of Brazil in the New World, afford rich and beautiful varieties of this gem.

Genus V.—EMERALD.

Rhombohedral. Prismatic. Cleavage rhombohedro-axotomous and peritomous, or prismatoidal. Hardness = 7.5,—8.0. Sp. gr. 2.6,—3.2.

1. Prismatic Emerald or Euclase.

Euclase, *Werner.*—Prismatischer Smaragd, *Mohs.*—Euclase, *Haüy.*

Specific Character.—Prismatic. Pyramid unknown. $P + \infty = 133^{\circ} 26'$. Combination hemiprismatic. $\bar{P}$
2
Cleavage, $Pr + \infty$. Very distinct. Hardness = 7.5. Sp. gr. = 2.9,—3.2.

Description.—Colours green, white, and blue. Occurs regularly crystallized. Lustre splendid. Fracture conchoidal. Transparent and translucent. Very easily frangible.

Constituent Parts.—Silica 43.22, alumina 30.56, glucina 21.78, oxide of iron 2.22, oxide of tin 0.70. *Berzelius.*

Geognostic and Geographic Situations.—This beautiful and rare mineral has been hitherto found only in Peru and Brazil.

2. Rhombohedral Emerald.

Rhomboedrischer Smaragd, *Mohs.*—Emeraude, *Haüy.*

Specific Character.—Rhombohedral, $R = 104^{\circ} 28'$. Combination dirhomboidal. $2(R) = 138^{\circ} 35' : 90$. Cleavage, $R - \infty$. Less perfect, $P + \infty$. Hardness = 7.5,—8.0. Sp. gr. = 2.6,—2.8.

Description.—Colours green, blue, yellow, and grey. Occurs regularly crystallized, and in thin prismatic concretions. Lateral planes longitudinally streaked or smooth. Lustre ranges from splendid to glistening, and is vitreous. Fracture conchoidal. Ranges from transparent to translucent on the edges. Easily frangible.

The varieties, with emerald-green colours, in short, smooth, transparent, and translucent prisms, with rough terminal planes, are named *precious emerald*, while the others, in which the colours are green, blue, yellow, and grey, and crystallized in long longitudinally streaked prisms, are named *beryl*, or *common emerald*.

Constituent Parts.—1. *Precious Emerald.* Silica 68.50, alumina 15.75, glucina 12.50, lime 0.25, oxide of chrome 0.30, oxide of iron 1.00. *Klaproth.*—2. *Beryl, Siberia.* Silica 66.45, alumina 16.75, glucina 15.50, oxide of iron 0.60. *Klaproth.*—3. *Beryl, Broddbo.* Silica 68.35, alumina 17.60, glucina 13.13, oxide of iron 0.72, oxide of tantalum 0.27. *Berzelius.*

Geognostic and Geographic Situations.—The precious emerald is found in mica-slate and clay-slate; the ancients obtained their emeralds from Mount Zalora in Upper Egypt, but at present the finest varieties are those imported from Peru. The beryl, or common emerald, occurs in Aberdeenshire, in the Mourne mountains in Ireland, the United States, &c.; but nearly all the varieties met with in trade, are brought from Russia.

Genus VI.—QUARTZ.

Rhombohedral prismatic. Cleavage not axotomous. Hardness = 5.5,—7.5. Sp. gr. = 1.9,—2.7.

1. Prismatic Quartz, or Iolite.

Prismatischer Quarz, *Mohs.*—Iolith. Peliom, *Werner.*—Iolithe, *Haüy.*—Dichroite. Cordierite. Steinheilite, *Auct.*

Specific Character.—Prismatic. Pyramid unknown. Cleavage, $P + \infty = 120^{\circ}$ nearly. $Pr + \infty$. (Fig. 30, 29.) Hardness = 7.0,—7.5. Sp. gr. = 2.5,—2.6.

Description.—Colour blue. Of an indigo blue colour, when viewed in the direction of the axis, but viewed perpendicular to the axis, is brownish-yellow. Occurs rarely crystallized, generally massive and disseminated. Lustre shining and vitreous. Fracture uneven and conchoidal. Translucent in the direction of the axis, and transparent at right angles to it.

Constituent Parts.—Silica 48.54, alumina 31.73, magnesia 11.30, oxide of iron 5.69, oxide of manganese 0.70, water or loss 1.65. *Stromeyer.*

Geognostic and Geographic Situations.—Occurs in granite and gneiss; Abo in Finland, Arendal in Norway, St Gothard in Switzerland, and Granatillo in Spain, Ujondlersok in Greenland, are localities of this mineral.

2. Rhombohedral Quartz.

Quartz, *Werner.*—Rhomboedrischer Quarz, *Mohs.*

Specific Character.—Rhombohedral. Rhombohedron = $75^{\circ} 55'$. Combination, hemirhomboidal and hemidirhomboidal. $R + n$ and $(P + n')^m$, with inclined planes, and $P + n''$ with parallel planes. Cleavage, $P = 133^{\circ} 44'$; $103^{\circ} 35'$. $P + \infty$. Hardness = 7.0. Sp. gr. = 2.5,—2.7.

Description.—Colours white, grey, rarely black, blue, green, yellow, red, and brown. Occurs regularly crystallized; in granular, fibrous, prismatic, and lamellar concretions; also massive, disseminated, in plates, stalactitic, reniform, botryoidal, globular, specular, vesicular, and cellular. Lustre ranges from splendid to glimmering, and is vitreous. Fracture conchoidal, even, uneven, and splintery. Ranges from transparent to opaque. Brittle, and easily frangible.

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The transparent and highly crystallized varieties are named *rock-crystal*. The pyramidal, translucent, and transparent varieties, having generally a violet-blue colour, and disposed in prismatic, fibrous, and lamellar concretions, are named *amethyst*. The massive, strongly translucent, rose-red, and milk-white varieties, are named *rose quartz*. Those varieties which have generally grey or white colours, the pyramidal form, and occur massive, disseminated, and in the various particular external forms enumerated above, with a low degree of translucency, are named *common quartz*. The leek-green translucent varieties, with a resino-vitreous lustre, and conchoido-splintery fracture, are named *prase*. The *cat's eye* is a variety, with a beautiful opalescence, like the light of the eye of the cat. Those opaque varieties, in which the colours are red, brown, and yellow, and the lustre shining externally, and glistening internally, and vitreo-resinous, and fracture small conchoidal, are named *iron-flint*. Those varieties which exhibit grey, yellow, brown, red, and green, generally muddy colours, and which occur massive, and in extraneous external shapes, with a splintery or conchoidal and dull or glimmering fracture, and are opaque or translucent on the edges, are named *hornstone*. The grey, brown, and black varieties which generally occur massive, and in various particular and extraneous external forms, and exhibit a glimmering lustre, conchoidal fracture, and feeble translucency, are named *flint*. The semi-transparent and translucent varieties, in massive and various particular external forms, with an even and dull fracture surface, are named *common calcedony*. The beautiful apple-green strongly translucent varieties are named *chrysoprase*. The grass-green varieties, with glimmering lustre, conchoidal fracture, and strong translucency, are named *plasma*. The semi-transparent and strongly translucent varieties, with glistening or shining vitreous lustre and conchoidal fracture, and with various tints of red, brown, yellow, green, and white, are named *carnelian*. The beautiful variety, named *heliotrope*, is well characterized, on a general view, by its green colour, and disseminated spots of red and yellow jasper. Those varieties, in which the colours are red, brown, and black, and seldomer yellow or green, which occur massive and disseminated, with a fracture ranging from conchoidal to earthy, and lustre from glistening to dull, and are opaque, are named *jasper*. And, lastly, the white and grey varieties, which are so porous and light, as to swim on the surface of water, are named *spongiform quartz*, or *floatstone*.

Constituent Parts.—1. *Rock-crystal*. Silica 99.37, trace of alumina and oxide of iron. *Bucholz*.—2. *Amethyst*. Silica 97.50, alumina 0.25, oxide of iron a trace, manganese 0.75. *Rose*.—3. *Common Quartz*. Silica 97.75, alumina 0.50, water 1.00. *Bucholz*.—4. *Red Iron-flint*. Silica 76.8, alumina 0.25, oxide of iron 21.66, volatile matter 1.00. *Bucholz*.—5. *Carnelian*. Silica 94.00, alumina 3.50, oxide of iron 0.75. *Bindheim*.—6. *Chrysoprase*. Silica 96.16, alumina 0.08, lime 0.82. *Klaproth*.—7. *Common Flinty Slate*. Silica 51.84, alumina 15.43, lime 9.42, oxide of iron 9.96. *Dumeril*.

Geognostic and Geographic Situations.—Quartz is very universally distributed, and, as far as we know at present, is the most abundant mineral in nature. It occurs in every rock, from granite to the newest secondary formation; and every country, every district in the world, afford examples of this mineral.

3. Uncleavable Quartz or Opal.

Untheilbarer Quarz, *Mohs*.

Specific Character.—Reniform. Massive. No cleavage. Hardness = 5.5,—6.5. Sp. gr. = 1.9,—2.2.

Description.—Colours white and grey, also green, yellow, brown, red, and black, and sometimes displays a beautiful play of colour. Occurs massive, and in various parti-

cular external forms. Lustre ranges from splendid to glistening, and is vitreous, or vitreo-resinous. Ranges from transparent to opaque.

The grey and white varieties, with glistening and shining pearly lustre, and translucent on the edges, or translucent in the mass, are named *quartz sinter*, or *pearl-sinter*. The yellowish and greyish white varieties with the botryoidal and other particular external forms, conchoidal fracture, and vitreous lustre, and which are strongly translucent, are named *hyalite*. The milk-white varieties, with the beautiful play of various rich and pure colours, are named *precious opal*. The transparent varieties, with the beautiful carmine-red and apple-green iridescence, are named *fire-opal*. Those varieties which are milk-white, and frequently dendritic, with a pearly, shining, or glistening lustre, conchoidal fracture, and complete opacity, are named *mother-of-pearl opal*, or *cacholong*. The *common opal* differs from the precious, principally in wanting the play of colour. The feebly translucent varieties, with conchoidal fracture, and glistening vitreo-resinous lustre, and white, grey, and brown colours, are named *semi-opal*. Those varieties, in which the colours are red, yellow, and grey, with a shining vitreo-resinous lustre, conchoidal fracture, and opacity, are named *jasper-opal*. Those varieties which occur in various vegetable forms, and are really vegetables impregnated, or petrified with opal, are named *wood-opal*. And lastly, the brown and yellowish grey tuberoso varieties are named *menilite*.

Constituent parts.—1. *Precious Opal*. Silica 90.0, water 10.0. *Klaproth*.—2. *Fire-Opal from Mexico*. Silica 92.60, water 7.75, oxide of iron 0.25. *Klaproth*.—3. *Common Opal, Hungary*. Silica 93.5, water 5.0, oxide of iron 1.0. *Klaproth*.—4. *Semi-Opal*. Silica 82.75, water 10.00, oxide of iron 3.00, alumina 3.50. *Stucke*.—5. *Hyalite*. Silica 92.00, water 6.33. *Bucholz*.—6. *Menilite*. Silica 85.5, water 10.0.

Geognostic and Geographic Situations.—This species has a comparatively limited geognostic and geographic distribution. The quartz sinter occurs in the vicinity of hot-springs, as in Iceland and other countries; the hyalite in secondary trap-rocks in Scotland, Germany; and the various opals are found principally in secondary trap, and in porphyry rocks in Hungary, Germany, Scotland and other countries.

4. Fusible Quartz, Obsidian, Pitchstone, Pearlstone, Pumice.

Empyrodox Quarz, *Mohs*.

Specific Character.—In grains... Massive. No cleavage. Hardness = 6.0,—7.0. Sp. gr. = 2.2,—2.4.

Description.—Colours black, green, and grey; also brown, blue, red, yellow, and white. Occurs in globular, lamellar, and prismatic concretions; massive, vesicular, and porous. Lustre ranges from splendid to glimmering, and is vitreous, resinous, and pearly. Ranges from transparent to opaque.

The varieties, with splendid and vitreous lustre, conchoidal fracture, and ranging from transparent to translucent on the edges, are named *obsidian*, and *marekanite*; those again in which the lustre is shining and resinous, and are translucent on the edges, are named *pitchstone*; the beautiful varieties in globular and concentric lamellar, shining, pearly, translucent concretions, are named *pearlstone*; and lastly, the white and grey varieties, which are vesicular and fibrous, with a vitreous or pearly lustre, and often so light as to swim on water, are named *pumice*.

Constituent Parts.—1. *Obsidian, from Mexico*. Silica 78.0, alumina 10.0, lime 1.0, potash 6.0, oxide of iron 3.6. *Vauquelin*.—2. *Marekanite*. Silica 81.00, alumina 9.50, lime 0.33, natron 4.50, potash 2.70, water and oxide of iron 1.00. *Klaproth*.—3. *Pitchstone*. Silica 72.80,

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Mineralogy. alumina 11.50, natron 2.85, lime 1.20, oxide of iron 3.03, water and bituminous matter 0.50.—4. *Pearlstone*. Silica 77.0, alumina 13.0, potash 1.5, lime and natron 2.7, oxide of iron and manganese 2.0, water 4.0. *Vauquelin*.—5. *Pumice*. Silica 77.50, alumina 17.50, natron and potash 3.00, oxide of iron with manganese 1.75. *Klaproth*.

Geognostic and Geographic Situations.—Pitchstone is found on the mainland of Scotland as in Dumfriesshire; in the Islands of Arran, Egg, Rum, and Skye; pearlstone occurs in great beauty in Hungary and Iceland, and both pumice and obsidian are productions of Iceland, the Lipari Islands, and Mexico.

Genus VII.—AXINITE.

Cleavage imperfect. Colour not inclining to yellow. Perfect vitreous lustre. Hardness = 6.5,—7.0. Specific gravity = 3.0,—3.3.

1. *Prismatic Axinite*.

Prismatischer Axinit, *Mohs*.—Thunerstein, *Werner*.—Axinite, *Häuy*.

Specific Character.—Prismatic. Pyramid unknown. Combination tetarto-prismatic. Cleavage, two faces, the one more distinct than the other. Incidence = $101^{\circ} 30'$.

Description.—Colours brown, blue, and sometimes grey and black. Occurs regularly crystallized; in curved lamellar concretions, and massive. Lustre externally splendid, internally glistening or shining, and vitreous. Ranges from transparent to feebly translucent. Brittle, and very easily frangible.

Constituent Parts.—Silica 45.00, lime 12.75, alumina 10.00, oxide of iron 12.25, oxide of manganese 9.00, boracic acid 2.00. *Wiegmann*.

Geognostic and Geographic Situations. Occurs in beds and veins in gneiss, mica-slate, clay-slate, and hornblende-slate. It occurs in small quantities in Cornwall, but nowhere else in Great Britain.

Genus VIII.—CHRYSLITE.

Prismatic. Colour green, brown, both inclining to yellow, yellow. Pure vitreous lustre. H = 6.5,—7.0. Sp. gr. = 3.15,—3.5.

1. *Prismatic Chrysolite*.

Prismatischer Chrysolithe, *Mohs*.—Peridot, *Häuy*.—Krisolith and Olivin, *Werner*.

Specific Character.—Prismatic. $\text{Pr} = 80^{\circ} 53'$, $(\bar{\text{P}} + \infty)^2 = 130^{\circ} 2'$. Cleavage $\text{Pr} + \infty$. Traces in the direction $\text{Pr} + \infty$. Colour green. Hardness = 6.5,—7.0. Sp. gr. = 3.3,—3.5.

Description.—Colour green. Occurs regularly crystallized. Lustre splendid and vitreous. Fracture conchoidal. Transparent.

The varieties in granular distinct concretions, and which have a lower degree of transparency and lustre than the more highly crystallized kinds, are those generally described under the name *olivine*.

Constituent Parts.—1. *Chrysolite*. Silica 39.0, magnesia 43.5, oxide of iron 19.0. *Klaproth*.—2. *Olivine from Unkel*. Silica 50.0, magnesia 38.5, oxide of iron 12.0. *Klaproth*.—3. *Olivine from Meteoric Iron*. Silica 38.18, magnesia 48.82, oxide of iron 11.19. *Stromeyer*.—Traces of Nickel were observed.

Geognostic and Geographic Situations.—The mineral occurs principally in secondary trap-rocks. The olivine variety is not unfrequent in some of the middle and western districts of Scotland. The chrysolites of commerce are brought from the Brazils and Upper Egypt.

2. *Hemiprismatic Chrysolite or Chondrodite*.

Brucite. Maclureite.

Specific Character.—Hemiprismatic. Cleavage scarcely

Mineralogy. visible. Colours yellow, brown. Hardness = 6.5. Sp. gr. = 3.15,—3.25.

Description.—Colours straw, ochre, honey, orange, passing into hyacinth-red and yellowish-brown. Occurs in imbedded grains in small massive pieces, and in longish granular distinct concretions. Lustre vitreous. Fracture imperfect conchoidal. Translucent.

Constituent Parts.—Magnesia 54.00, silica 32.66, fluoric acid 4.08, oxide of iron 2.33, potash 2.10, water 1.00. *Seybert*.

Geognostic and Geographic Situations.—Occurs in calc spar and granular limestone in the parish of Pargas in Finland; also in granular limestone, associated with graphite, at Newton in New Jersey, United States, at Lochness, and in granular limestone in Kincardineshire.

Genus IX.—BORACITE.

Tessular. Hardness = 7. Sp. gr. = 2.8,—3.0.

1. *Octahedral Boracite*.

Octaedrischer Borazit, *Mohs*.—Borazit, *Werner*.—Magnesie Boratée, *Häuy*.

Specific Character.—Tessular. Combination semitesular of inclined planes. Cleavage octahedral but imperfect.

Description.—Colours white and grey. Occurs in cubes and dodecahedrons. Internally shining, and nearly adamantine. Fracture conchoidal. Translucent and transparent.

Constituent Parts.—1. Boracic acid 54.55, magnesia 30.68, oxide of iron 0.57, silica 2.27. *Pffaff*.—2. Boracic acid 69.95, magnesia 30.04. *Arfwedson*.

Geognostic and Geographic Situations.—Occurs imbedded in gypsum, in the Kalkberg, in Hanover, and in the Segeberg, near Kiel, in Holstein.

Genus X.—TOURMALINE.

Rhombohedral. Hardness = 7.0,—7.5. Sp. gr. = 3.0—3.2.

1. *Rhombohedral Tourmaline*.

Rhomboedrischer Tourmaline, *Mohs*.—Tourmaline, *Häuy*.

Specific Character.—Rhombohedral. Rhombohedron = $133^{\circ} 26'$. Combination hemirhombohedral, the opposite ends differently formed. Cleavage, R. $\text{P} + \infty$, imperfect.

Description.—Colours black, brown, green, blue, red, and white. Occurs regularly crystallized; in prismatic and granular distinct concretions, massive and disseminated. Lustre ranges from splendid to glistening, and is vitreous. Fracture conchoidal and uneven. Ranges from transparent to opaque. Brittle and easily frangible.

The black coloured opaque varieties, with uneven fracture, are named *schorl*; all the others are ranged under the title *tourmaline*.

Constituent Parts.—1. *Black or Schorl of Rabenstein*. Silica 34.48, alumina 34.75, soda 1.75, potash 0.48, oxide of iron 17.44, oxide of manganese 1.89, boracic acid 4.02, magnesia 4.68. *Gmelin*.—2. *Blue Tourmaline, Uton*. Silica 40.30, alumina 40.50, oxide of iron 4.85, oxide of manganese 1.50, boracic acid 1.10, lithion 4.39. *Arfwedson*.—3. *Green Tourmaline, Brazil*. Silica 39.16, alumina 40.00, oxide of iron 5.96, oxide of manganese 2.14, boracic acid 4.59, lithion 3.59. *Gmelin*.—4. *Red Tourmaline, Siberia*. Silica 39.37, alumina 44.00, potash 1.29, oxide of manganese 5.02, boracic acid 4.18, lithion 2.62. *Gmelin*.

Geognostic and Geographic Situations.—It occurs imbedded in granite, gneiss, mica-slate, talc-slate, chlorite-slate, dolomite, topaz-rock, and quartz-rock; also in felspar, mica, talc, &c. and in alluvial strata. The schorl varieties occur in various primitive rocks in the alpine districts of Scotland, and the purer varieties, or tourmaline, properly

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so called, are met with in Siberia, Spain, and many other countries.

Genus XI. GARNET.

Tessular, pyramidal, prismatic. Lustre not pure vitreous. Hardness = 6.0,—7.5. Sp. gr. = 3.1,—4.3. If colour red, the sp. gr. = 3.7, and more. If colour black, sp. gr. = 3.9, and less. If hardness 7.5, the colour is red or brown. If sp. gr. less than 3.3, is tessular.

1. *Pyramidal Garnet or Vesuvian.*

Pyramidaler Granat, *Mohs*.—Vesuvian and Egeran, *Werner*.—Idocrase, *Häuy*.

Specific Character.—Pyramidal. Pyramid = $129^{\circ} 29'$; $74^{\circ} 14'$. Cleavage, $P = \infty$. $P + \infty$. [$P + \infty$]. Hardness = 6.5. Sp. gr. = 3.3,—3.4.

Description.—Colours green and brown, and rarely blue. Occurs regularly crystallized; in granular distinct concretions; massive, and disseminated. Externally splendid, and internally feebly shining and vitreo-resinous. Fracture uneven, inclining to small conchoidal. Ranges from transparent to translucent in the edges.

Constituent Parts.—Silica 38.85, alumina 21.93, lime 33.61, oxide of iron 5.40. *Kobell*.

Geognostic and Geographic Situations.—Occurs in primitive rocks in Ireland, also in Scotland; and on the continent of Europe the most beautiful varieties are there found in the ejected masses in Somma, near Naples, where they are associated with granular limestone, garnet, hornblende, mica, chlorite, augite, meionite, nepheline, magnetic iron-ore, &c.

2. *Tetrahedral Garnet, or Helvine.*

Helvin, *Werner*.—Tetraedrischer Granat, *Mohs*.

Specific Character.—Tessular. Combination semi-tessular of inclined planes. Cleavage octahedral, but imperfect. Hardness = 6.0,—6.5. Sp. gr. = 3.1,—3.3.

Description.—Colours wax-yellow, inclining to yellowish-brown or siskin-green. Occurs regularly crystallized, in tetrahedrons, truncated on the angles, and in granular distinct concretions. Lustre ranges from splendid to glistening and vitreo-resinous. Fracture uneven. Translucent, or translucent on the edges. Streak white.

Constituent Parts.—Silica 35.27, alumina 1.45, oxide of iron 7.99, oxide of manganese 29.44, sulphate of manganese 14.00, glucina 8.03. *Gmelin*.

Geognostic and Geographic Situations.—Occurs in a bed in gneiss, associated with fluor-spar, slate-spar, chlorite, quartz, blende, and copper-pyrites, near Schwarzenberg, in Saxony, also in brown ironstone, near Breitenbrunn, also in Saxony.

3. *Dodecahedral Garnet.*

Specific Character.—Tessular. Cleavage dodecahedral, imperfect. Hardness = 6.5,—7.5. Sp. gr. = 3.5,—4.3.

Description.—Colours red, brown, green, black, grey, and yellow. Occurs regularly crystallized; in angulo-granular concretions, and massive. Lustre ranges from splendid to glimmering, and is vitreous inclining to resinous, resino-vitreous, and resino-adamantine. Fracture conchoidal, splintery, uneven. Ranges from transparent to opaque.

The asparagus-green varieties in leucite formed crystals are named *grossular*; the greyish-black dodecahedral opaque varieties, which externally have a metallic-like aspect, *pyrenaite*; the velvet-black, dodecahedral opaque varieties, *melanite*; the green, brown, and grey massive varieties, with glimmering lustre, and feeble translucency on the edges, *allochroite*; the brown and red varieties in granular concretions, with resino-adamantine lustre, *colophonite*; the red highly crystallized transparent varieties, *precious*

garnet; the yellow nearly transparent varieties, *topazolite* or *yellow garnet*; the brown and green varieties, in crystals often rounded on the edges, in granular concretions, and translucent, or translucent on the edges, *common garnet*; the deep blood-red variety in roundish and angular grains, and completely transparent, *pyrope*; and the hyacinth and orange-yellow varieties, in granular distinct concretions, and massive, with resino-vitreous lustre, conchoidal fracture, and transparent or translucent, are named *Essonite* or *Cinnamon Stone*.

Constituent Parts.—1. *Grossular*. Silica 40.55, alumina 20.10, lime 34.86, oxide of iron 5.00, oxide of manganese 0.48. *Wachtmeister*.—2. *Pyrenaite*. Silica 43.0, alumina 16.0, lime 20.0, oxide of iron 16.0, water 4.0. *Vauquelin*.—3. *Melanite*. Silica 35.5, alumina 6.0, lime 32.5, oxide of iron 25.2, oxide of manganese 0.4.—4. *Allochroite*. Silica 35.0, alumina 8.0, lime 30.0, oxide of iron 17.0, oxide of manganese 3.5. *Vauquelin*.—5. *Colophonite*. Silica 37.0, alumina 13.5, lime 29.0, oxide of iron 7.5, oxide of manganese 4.8, magnesia 6.5, water 1.0. *Simon*.—6. *Precious Garnet*. Silica 35.75, alumina 27.25, oxide of iron, 36.00, oxide of manganese 0.25. *Klaproth*.—7. *Pyrope*. Silica 40.0, alumina 28.5, lime 3.5, oxide of iron 16.5, oxide of manganese 0.3, magnesia 10.0, chromic acid 2.6.—8. *Essonite or Cinnamon Stone*. Silica 38.80, alumina 21.26, lime 31.25, oxide of iron 6.50. *Klaproth*.

Geognostic and Geographic Situations.—This mineral occurs principally in primitive rocks, either disseminated, or forming an ingredient in the composition of subordinate beds; it is comparatively rare in transition rocks, and is still less frequently met with in secondary formations. In Scotland the *precious garnet* is common in several Highland districts in Perthshire, Aberdeenshire, &c.; the *pyrope* variety occurs in secondary trap-rocks in Fifeshire; the *cinnamon stone* or *essonite* in gneiss in Kincardineshire; the *melanite* or black garnet is found in Vesuvius, and in the neighbourhood of Rome; the *grossular* is met with near the river Willui in Siberia; the *pyrenaite* in the Pic Eres Lids, near Barèges, in the Pyrenees; the *colophonite* chiefly at Arendal, in Norway; *allochroite* in the neighbourhood of Drammen, in Norway; and the finest *cinnamon stones* are the produce of Ceylon.

4. *Prismatoidal Garnet, or Grenatite.*

Prismatoidischer granat, *Mohs*.—Granatit, *Werner*.—Staurotide, *Häuy*.

Specific Character.—Prismatic. Pyramid = $121^{\circ} 54'$; $80^{\circ} 43'$; $124^{\circ} 48'$. $P + \infty = 129^{\circ} 30'$. Cleavage, $P + \infty$, perfect. Traces in direction $(\bar{P} + \infty)^2$. (Fig. 29.) Hardness = 7.0,—7.5. Sp. gr. = 3.3,—3.9.

Description.—Colour reddish-brown. Occurs regularly crystallized. Internally the cleavage is shining and splendid; fracture glistening and glimmering, and resino-vitreous. Fracture uneven. Ranges from semi-transparent to opaque. Streak white.

Constituent Parts.—Silica 33.00, alumina 45.00, lime 3.84, oxide of iron 13.00, oxide of manganese 4.00. *Vauquelin*.

Geognostic and Geographic Situations.—Occurs in primitive rocks in the Shetland Islands, in Aberdeenshire, and other parts of Scotland.

Genus XII.—ZIRCON.

Pyramidal. Hardness = 7.5. Sp. gr. = 4.5,—4.7.

1. *Pyramidal Zircon.*

Pyramidaler Zircon, *Mohs*.

Specific Character.—Pyramidal. Pyramid = $123^{\circ} 19'$; $84^{\circ} 20'$. Cleavage, $P, P + \infty$.

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Description.—Colours grey and hyacinth red; also white, green, brown, and rarely yellow, blue, and red. Occurs regularly crystallized. Lustre splendid, shining, and adamantine-resinous and resino-vitreous. Fracture conchoidal. Ranges from transparent to opaque.

Those varieties in which the cleavage is very distinct, and which have frequently a hyacinth-red colour, are named *hyacinth*, the other varieties *common zircon*.

Constituent Parts.—1. *Zircon*. Zirconia 69.0, silica 26.5, oxide of iron 0.5. *Klaproth*.—2. *Hyacinth*. Zirconia 70.0, silica 25.0, oxide of iron 0.5. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in syenite, granite, gneiss, primitive trap, in secondary trap, and ejected masses of Somma. The syenite rocks of Galloway, the gneiss rocks of Inverness-shire, and of the Shetland Islands, afford examples of this mineral. The most esteemed varieties of zircon, are from the Island of Ceylon.

Order VIII.—ORE.

Streak not green. Hardness = 2.0,—7.0. Sp. gr. = 3.4,—7.4. If metallic, the colour is black. If not metallic, the lustre is adamantine or imperfect metallic. If streak yellow or red, the hardness equal 3.5 and more; and sp. gr. 4.8 or more. If streak brown or black, the hardness is equal to 5.0 or more, or 2.5 and less; or single distinct cleavage. If hardness is 2.5 or less, the specific gravity is under 5.0. If hardness is 4.5 or less, the streak is yellow, red, or black. If hardness equal to 6.5 or more, and streak uncoloured, the specific gravity equal 6.5 and more.

Genus I.—MELANE-ORE.

Prismatic. Black. Streak greenish and brownish-grey. Hardness = 5.5,—7.5. Sp. gr. = 3.2,—4.3.

1. *Prismatic Melane-Ore or Gadolinite.*

Gadolinite.—*Mohs*, *Häuy*, and *Haidinger*.

Specific Character.—Indistinct crystals which are prisms of about $109^{\circ} 28'$. Colour greenish-black. Streak greenish-grey. Hardness = 6.5—7.0. Sp. gr. = 4.2,—4.3.

Description.—Colours black, or greenish-black. Occurs massive; in granular and prismatic concretions. Internally shining, and lustre resino-vitreous. Fracture conchoidal, seldom uneven. Opaque, or very faintly translucent on the edges.

Constituent Parts.—Yttria 45.93, protoxide of iron 11.34, protoxide of cerium 16.90, silica 24.16. *Berzelius*.

Geognostic and Geographic Situations.—Occurs in beds of felspar, or mica-slate at Ytterby, and in granite at Finbo, in Sweden; also in Disco Island in Davis' Straits, and in granite in the Island of Ceylon.

2. *Anorthitic Melane-Ore or Allanite.*

Anorthisches Melan-Erz including Orthite, *Haidinger*.

Specific Character.—Tetarto-prismatic. Prism = 115° —deeply truncated on the obtuse edges. Cleavage imperfect. Greenish and brownish-black. Streak greenish and brownish-grey. Hardness = 5.5,—6.0. Sp. gr. = 3.2,—3.6.

Description.—Colours black, inclining to green, grey, or brown. Occurs massive or in acicular crystals. Lustre imperfect, metallic. Fracture conchoidal. Opaque. Streak greenish or brownish-grey.

Constituent Parts.—1. *Allanitic Melane-Ore*. Oxide of cerium 33.9, oxide of iron 25.4, silica 35.4, lime 9.2, alumina 4.1, water 4.0. *Thomson*.—2. *Orthitic Melane-Ore*. Silica 32.00, lime 7.84, alumina 14.80, oxide of cerium 19.44, protoxide of iron 12.44, oxide of manganese 3.40, yttria 3.44, water 5.36. *Berzelius*.

Geognostic and Geographic Situations.—The Allanite varieties occur at Alluk, near the southern extremity of Old Greenland. The varieties named Orthite occur in quartz at Finbo, near Fahlun, in Sweden, and in granite

at Skeppsholm, one of the islands on which Stockholm is built, also at Lindenaes, in Norway, and in Greenland. It was named in honour of the late Mr Thomas Allan, one of our best mineralogists, and distinguished as an accurate and judicious geologist.

Genus II.—TITANIUM-ORE.

Pyramidal, prismatic. Streak white, or very pale brown. Hardness = 5.0,—6.5. Sp. gr. = 3.4,—4.4. If the sp. gr. less than 4.2, the streak is white.

1. *Hemiprismatic Titanium-Ore, or Sphene.*

Prismatisches Titan-erz, *Mohs*.—Gelb and Braun, *Ma-nak-erz*, *Werner*.—Titane Siliceo-calcaire, *Häuy*.—Hemiprismatisches Titan-erz, *Haidinger*.

Specific Character.—Prismatic. Pyramid = $111^{\circ} 12'$; $88^{\circ} 47'$; $131^{\circ} 16'$. $P + \infty = 103^{\circ} 20'$. Combination hemiprismatic. $\frac{P}{2} = 111^{\circ} 12'$. Cleavage, $\frac{P}{2}$. (Fig. 37).

Streak white. Hardness = 5.0,—5.5. Sp. gr. = 3.4,—3.6.

Description.—Colours brown, yellow, green, grey, and white. Occurs regularly crystallized; in granular and lamellar distinct concretions, and massive. Lustre ranges from splendid to glistening, and is adamantine. Fracture conchoidal. Ranges from transparent to opaque.

One set of varieties, in which brown is the predominating colour, is named *common sphene*, or *brown titanium-ore*; and another, in which the principal colours are yellow, and the cleavage distinct, is named *yellow titanium-ore*, or *foliated sphene*.

Constituent Parts.—Oxide of titanium 33.0, silica 35.9, lime 33.0, trace of manganese. *Klaproth*.

Geognostic and Geographic Situations.—This mineral occurs imbedded in syenite in Inverness-shire, Perthshire, Galloway, and many other quarters of Scotland; it also occurs in syenite rocks in England.

2. *Octahedral Titanium-Ore, or Pyrochlore.*

Octaedrisches Titan-erz, *Mohs*.—Pyrochlor, *Wöhler*.

Specific Character.—Tessular. Cleavage scarcely perceptible. Streak pale brown. Hardness = 5.0. Sp. gr. = 4.2,—4.25.

Description.—Colour dark reddish-brown, passing into blackish-brown. Streak pale brown. Occurs massive, disseminated, and in small octahedrons. Lustre shining and vitreo-resinous. Fracture conchoidal. From translucent on the edges to opaque.

Constituent Parts.—Titanic acid 62.75, lime 12.85, protoxide of uranium 5.18, oxide of cerium 6.80, protoxide of manganese 2.75, oxide of tin 0.61, oxide of iron 2.16, water 4.20. *Wöhler*.

Geognostic and Geographic Situations.—Occurs imbedded in syenite at Laurvig and Frederickswürn, Norway; also in Greenland.

3. *Peritinous Titanium-Ore, or Rutile.*

Peritomes Titan-erz, *Mohs*.—Titan-oxydé, *Häuy*.—Rutil, *Nigrine*, *Werner*.—Titan schorl. *Sagenite*.

Specific Character.—Pyramidal. Pyramid = $117^{\circ} 2'$; $95^{\circ} 13'$. Cleavage, $P + \infty$. $[P + \infty]$. Streak pale brown. Hardness = 6.0,—6.5. Sp. gr. = 4.2,—4.4.

Description.—Colours brown, red, yellow, and sometimes nearly velvet black. Occurs regularly crystallized, massive, disseminated, in angular grains and in flakes. Lustre metallo-adamantine and adamantine, and ranges from splendid to glistening. Fracture conchoidal. Ranges from transparent to opaque.

The dark brown and black opaque varieties are named *nigrine*; the others *rutile*.

Constituent Parts.—The pure varieties contain of titanium 56.05, and oxygen 33.35; the black varieties, named

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nigrine, contain oxide of titanium 84.0, oxide of iron 14.0, oxide of manganese 2.0.

Geognostic and Geographic Situations.—The rutile varieties occur in the granite of Cairngorm; at Killin, and in Ben-Gloe, in quartz-rock. The nigrine varieties are met with at Ely, in Fifeshire, and also in Bohemia and Transylvania.

4. Pyramidal Titanium or Anatase.

Pyramidales Titan-erz, *Mohs*.—Octaedrit, *Werner*.—Titane, Anatase, *Häuy*.—Oisanite, *Lameth*.

Specific Character.—Pyramidal. Pyramid = $70^{\circ} 56'$; $136^{\circ} 22'$. Cleavage, P — ∞ . P. perfect. Streak white. Hardness = 5.5,—6.0. Sp. gr. = 3.8,—3.9.

Description.—Colours blue and brown. Occurs regularly crystallized. Lustre splendid and adamantine, inclining to semi-metallic. Translucent and transparent.

Constituent Parts.—Is a pure oxide of titanium.

Geognostic and Geographic Situations.—Occurs in small veins in primitive rocks, as greenstone, gneiss, mica-slate, clay-slate, granite, in Dauphiny, Spain, Norway, and Brazil.

5. Prismatic Titanium-Ore, or Brookite.

Prismatisches Titan-erz, *Haidinger*.—Brookite, *Levy*.

Specific Character.—Prismatic. Prism = 160° . Colour hair-brown. Streak yellowish-white. Hardness = 5.5,—6.0. Sp. gr. unknown.

Description.—Colour hair-brown, inclining to dark orange-yellow and red. Streak yellowish-white. Lustre metallic, adamantine. Translucent or opaque. Brittle.

Constituent Parts.—Chiefly composed of oxide of titanium.

Geognostic and Geographic Situations.—Occurs along with quartz and anatase at Bourg d'Oisans in Dauphiny, the Tete-Noire in Savoy, and in the mountain of Snowdon in Wales.

Genus III.—ZINC-ORE, or RED OXIDE of ZINC.

Prismatic. Streak orange-yellow. Hardness = 4.0,—4.5. Sp. gr. = 5.4,—5.5.

1. Prismatic Zinc-Ore.

Prismatisches Zink-erz, *Mohs* and *Haidinger*.—Red Oxyd of Zink, Zinc Oxide Ferrifere Lamellaire Brun-Rougeatre, *Häuy*.

Specific Character.—Prismatic. Cleavage in the direction of a rhombic prism of about 120° and its shortest diagonal.

Description.—Colour between blood-red and aurora-red. Streak orange-yellow. Massive, disseminated, and in granular concretions. Lustre adamantine, and shining. Translucent on the edges. Fracture conchoidal. Brittle.

Constituent Parts.—Oxide of zinc 92.0, oxides of iron and manganese 8.0. *Bruce*.—Oxide of zinc 88.0, oxides of iron and manganese 12.0. *Berthier*.

Geognostic and Geographic Situations.—This important ore has hitherto been found only in America, where it occurs along with calcareous spar, and Franklinite at Sparta, in New Jersey.

Genus IV.—RED COPPER-ORE.

Tessular. Streak brownish-red. Hardness = 3.5,—4.0. Sp. gr. = 5.6,—6.1.

1. Octahedral Red Copper-Ore.

Octaedrisches Kupfererz, *Mohs*.—Roth Kupfererz, *Werner*.—Cuivre oxydulé and Cuivre oxide rouge, *Häuy*.

Specific Character.—Tessular. Cleavage octahedral.

Description.—Colours red, particularly cochineal-red. Occurs crystallized, frequently the cubo-octahedron; in granular distinct concretions; massive, disseminated, and in flakes. Lustre ranges from shining to glimmering, and

is adamantine, inclining to semi-metallic. Fracture uneven. Ranges from translucent to opaque. Brittle.

The varieties with cleavage are named *foliated red copper-ore*; those which are massive, glistening, and opaque, *compact red copper-ore*; and the varieties in capillary crystals, *capillary red copper-ore*.

Constituent Parts.—Copper 88.5, oxygen 11.5. *Chenevix*.

Geognostic and Geographic Situations.—Occurs in veins in gneiss, mica-slate, clay-slate, and greywacke; also in veins and beds in secondary rocks. The copper mines of Cornwall afford fine examples of this beautiful ore.

Genus V.—TIN-ORE.

Zinn-erz, *Mohs*.

Pyramidal. Streak not black. Hardness = 6.0,—7.0. Sp. gr. = 6.3,—7.1.

1. Pyramidal Tin-Ore.

Pyramidales Zinn-erz, *Mohs*.

Specific Character.—Pyramidal. Pyramid = $133^{\circ} 26'$; $67^{\circ} 59'$. Cleavage P + ∞ . [P + ∞]. Streak white or pale brown.

Description.—Colours brown, black, green, white, yellow, and red. Occurs regularly crystallized, very generally in four-sided prisms acuminate with four planes, and often in twin crystals; also reniform, botryoidal, and globular, and in delicate fibrous concretions. Externally splendid; internally ranges from splendid to glimmering, and is adamantine, inclining to resinous. Fracture uneven. Ranges from semi-transparent to opaque.

The varieties in fibrous concretions are named *wood-tin*, the others *common tinstone*.

Constituent Parts.—Oxide of tin 95.0, oxide of iron 5.0. *Descotils*.

Geognostic and Geographic Situations.—Occurs in granite, gneiss, mica-slate, clay-slate, porphyry, and in alluvial depositions. The mines of Cornwall afford all its varieties.

Genus VI.—WOLFRAM-ORE.

Scheel-erz, *Mohs*.

Prismatic. Streak dark reddish-brown. Hardness = 5.0,—5.5. Sp. gr. = 7.1,—7.4.

1. Prismatic Wolfram.

Prismatisches Scheel-erz, *Mohs*.—Wolfram, *Werner*.—Scheelin ferruginé, *Häuy*.

Specific Character.—Prismatic. Oblique prism = $105^{\circ} 5'$, and $78^{\circ} 56'$. Cleavage Pr + ∞ , perfect. (Fig. 29.)

Description.—Colour brownish-black. Occurs regularly crystallized, and massive. Lustre ranges from splendid to glistening, and is adamantine, inclining to semi-metallic. Fracture uneven. Opaque.

Constituent Parts.—Tungstic acid 78.77, protoxide of manganese 6.22, protoxide of iron 18.32, silica 1.25. *Berzelius*.

Geognostic and Geographic Situations.—Occurs in primitive rocks in the island of Rona, one of the Hebrides, in Cornwall, in the Saxon and Bohemian tin-mines, &c.

Genus VII.—TANTALUM-ORE.

Tantal-erz, *Mohs*.

Prismatic. Streak brownish-black. Hardness = 6.0. Sp. gr. 6.0,—6.3.

1. Prismatic Tantalum-Ore.

Prismatisches Tantal-erz, *Mohs*.

Specific Character.—Prismatic. Cleavage prismatic.

Description.—Colour black. Occurs regularly crystallized; massive and disseminated. Lustre shining and glis-

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Constituent Parts.—Oxide of tantalum 67.6, oxide of tin 8.7, oxide of iron 7.6, oxide of manganese 5.9, oxide of scheelium 8.7, lime 1.5. *Berzelius.*

Geognostic and Geographic Situations.—Occurs in granite in Finland; in granite, along with beryl, iolite, uranmica, and iron-pyrites, at Bodenmais in Bavaria, also in North-America.

Observations.—Berzelius mentions a variety of this species with a pitch-black streak, and of rather higher specific gravity, which he thinks may prove a new species.

Genus VIII.—FERGUSONITE.

Fergusonite, *Haidinger.*

Pyramidal. Colour brownish-black. Streak pale brown. Hardness = 5.5,—6.0. Sp. gr. = 5.8,—5.9.

1. *Pyramidal Fergusonite.*

Specific Character.—Pyramidal. Terminal edge = 100° 28', edge of base = 128° 27'.

Constituent Parts.—Columbic acid 47.75, yttria 41.91, oxide of cerium 4.68, zirconia 3.02, oxide of tin 1.00, oxide of uranium 0.95, oxide of iron 0.34. *Hartwall.*

Geognostic and Geographic Situations. This interesting mineral occurs in quartz, at Kikertausak, near Cape Farewell, in Greenland, where it was found by Gieseke. It is named in honour of an excellent mineralogist, Mr Ferguson of Raith.

Genus VIII.—URANIUM-ORE.

Uran-erz, *Mohs.*

Form unknown. Streak black. Hardness = 5.5. Sp. gr. = 6.4,—6.6.

1. *Uncleavable Uranium-Ore.*

Untheilbares Uran-erz, *Mohs.*—Uran-pecherz, *Werner.*—Uran oxydulé, *Häuy.*

Specific Character.—Uncleavable, reniform, and massive. No cleavage.

Description.—Colour greyish-brown and velvet-black. Occurs massive, and reniform. Lustre shining, and adamantine, inclining to semi-metallic. Fracture conchoidal, passing into uneven. Opaque.

Constituent Parts.—Protoxide of uranium 86.5, protoxide of iron 2.5, silica 5.0, sulphuret of lead 6.0. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in veins in primitive rocks, along with native silver, red silver, iron and copper pyrites, galena, blende, and brown-spar, in Saxony, Bohemia, and Hungary. The only British locality is Cornwall.

Genus IX.—CERIUM-ORE.

Cerer-erz, *Mohs.*

Rhombohedral. Streak white. Hardness = 5.5. Sp. gr. = 4.9,—5.0.

1. *Rhombohedral Cerium-Ore.*

Rhomboedrisches Cerer-erz, *Haidinger.*

Untheilbares Cerer-erz, *Mohs.*—Cerer-erz, *Werner.*—Cerium oxidé silicifère, *Häuy.*

Specific Character.—Rhombohedral. Low regular six-sided prisms. Massive. Traces of cleavage.

Description.—Colours red and brown. Occurs massive and disseminated. Internally glimmering and adamantine. Fracture splintery. Opaque.

Constituent Parts.—Oxide of cerium 68.59, silica 18.00, oxide of iron 2.00, lime 1.25, water and carbonic acid 9.60. *Hisinger.*

Geognostic and Geographic Situations.—Occurs in a bed of copper pyrites in gneiss, near Ridderhyttan, in Westmannland, in Sweden.

* *Cerine.*

Cerium Oxide Siliceux Noire, *Häuy.*

Colour brownish-black. Prismatic. Cleavage prismatic. Streak yellowish-grey. Hardness = 5.0.—60. Sp. gr. = 4.1,—4.2. Found in Sweden.

Constituent Parts.—Silica 30.17, alumina 11.31, lime 9.12, oxide of cerium 28.19, oxide of iron 20.72.

Genus X.—CHROME-ORE.

Chrom-erz, *Mohs.*

Tessular. Streak brown. Hardness = 5.5. Sp. gr. = 4.4,—4.5.

1. *Octahedral Chrome-Ore, or Chromate of Iron.*

Octaedrisches Chrom-erz, *Mohs.*—Chrom-eisenstein, *Werner.*—Fer chromaté, *Häuy.*

Specific Character.—Tessular. Cleavage octahedral, but imperfect.

Description.—Colour iron-black or brownish-black. Occurs regularly crystallized; also in granular distinct concretions; massive and disseminated. Internally shining and glistening, and imperfect metallic. Fracture uneven. Opaque.

Constituent Parts.—Oxide of chrome 60.04, protoxide of iron 20.13, alumina 11.85, magnesia 7.45. *Abich.*

Geognostic and Geographic Situations.—Occurs in imbedded masses, and in veins in serpentine, porphyry, and secondary trap. In Scotland it occurs principally in serpentine rocks, and more abundantly in the Shetland Islands than in any other quarter.

Genus XI.—IRON-ORE.

Eisen-erz, *Mohs.*

Tessular, rhombohedral, prismatic. Streak red, brown, black. Hardness = 5.0,—6.5. Sp. gr. = 3.8,—5.3. If the streak is brown, the specific gravity is equal to 4.2, and less, and form prismatic; or = 4.8, and more. If the streak is black, and the specific gravity = 4.8, and more, it acts on the magnet. If the specific gravity is under 4.3, and the colour black, the streak is not shining.

1. *Octahedral Iron-Ore.—Black or Magnetic Iron-Ore.*

Octaedrisches eisenerz, *Mohs.*—Fer oxydulé, *Häuy.*—Magnet-eisenstein, *Werner.*

Specific Character.—Tessular. Cleavage octahedral. Streak black. Hardness = 5.5,—6.5. Sp. gr. = 4.8,—5.2.

Description.—Colour iron-black. Occurs regularly crystallized; in granular distinct concretions; and in loose grains; massive and disseminated. Lustre ranges from splendid to glistening, and is metallic. Fracture uneven, or conchoidal. Opaque. It is magnetic.

The variety in grains is named *iron-sand*. The other varieties, *common magnetic iron-ore*.

Constituent Parts.—It contains 28.22 per cent. of oxygen.

Geognostic and Geographic Situations.—Occurs in beds, often of vast thickness and great extent, in rocks of the older formations, as gneiss, mica-slate, hornblende-slate, clay-slate, and primitive greenstone; also variously disposed in granite, syenite, serpentine, and chlorite-slate; less frequently in transition-rocks, in veins, beds, and imbedded masses, as in transition porphyry; and still less frequently in secondary trap-rocks. The serpentine, chlorite, and gneiss-rocks of the Shetland Islands afford examples of this ore; the same is the case on the Mainland of Scotland, both in primitive and secondary rocks. The great beds of iron-ore at Arendal in Norway, and nearly all the iron-mines in Sweden, are of magnetic iron-ore.

2. *Rhombohedral Iron-Ore.—Iron-Glance.—Red Iron-Ore.—Red Hematite.*

Rhomboedrisches Eisen-erz, *Mohs.*—Fer oligiste, *Häuy.*

Specific Character.—Rhombohedral. Rhombohedron

Mineralogy. = 85° 58'. Cleavage R, sometimes R — 8. Streak red, reddish-brown. Hardness = 5.5,—6.5. Sp. gr. = 4.8,—5.3.

Description.—Colours dark steel-grey bordering on iron-black, iron-black, and brownish-red. Occurs regularly crystallized; in granular, lamellar, and fibrous distinct concretions; massive, disseminated, reniform, botryoidal, stalactitic, and globular. Lustre ranges from splendid to dull, and is metallic and semi-metallic. Fracture conchoidal or earthy. Ranges from translucent to opaque.

The dark steel-grey and iron-black varieties, which are generally more or less regularly crystallized, are named *specular iron-ore*, or *iron-glance*; the red varieties are named *red iron-ore*.

Constituent Parts.—Specular iron-ore is a peroxide of iron, the proportion of metal to that of oxygen being as 69.34 to 30.66. Red hematite affords of peroxide of iron 94.0, silica 2.0, lime 1.0, water 3.0. *Daubuisson*.

Geognostic and Geographic Situations.—The specular iron-ore occurs in gneiss, granite, mica-slate, transition clay-slate, greywacke, and less frequently in secondary rocks. The island of Elba affords the richest and most beautiful varieties of specular iron-ore, and specimens of considerable beauty are met with in Fitful-head in Shetland, and near Dunkeld in Perthshire. The red iron-ore occurs also in primitive rocks, but less frequently than in those of the transition class, as greywacke and transition clay-slate; and considerable depositions of it are met with in secondary limestone districts. Ulverstone, in Lancashire, and other parts of England, afford beds and veins of this ore.

3. Prismatic Iron-Ore.

Prismatisches Eisen-erz, Mohs.—Braun Eisenstein, *Werner*.—Fer oxydé, *Haüy*.—Fer Hydraté, *Daubuisson*.

Specific Character.—Prismatic. Pr = 117° 30'. P + ∞ = 130° 14'. Cleavage = P + ∞. Streak yellowish-brown. Hardness = 5.0,—5.5. Sp. gr. = 3.8,—4.2.

Description.—Colours brown and yellow. Occurs regularly crystallized; in granular, fibrous, and lamellar distinct concretions; massive, stalactitic, coralloidal, reniform, botryoidal, tuberoso, cylindrical, and fruticose. Lustre glimmering and semi-metallic, inclining more or less to adamantine. Fracture uneven, even, conchoidal, or earthy. Translucent on the edges, or opaque.

Constituent Parts.—*Hematitic or fibrous variety.* Peroxide of iron 82.0, water 14.0, oxide of manganese 2.0, silica 1.0, *Daubuisson*.—*Compact variety.* Peroxide of iron 84.0, water 11.0, oxide of manganese 2.0, silica 2.0, *Daubuisson*. It is thus a hydriated peroxide of iron; the proportion of peroxide of iron and water being as 85.30 to 14.70.

Geognostic and Geographic Situations.—Occurs in veins, beds, lenticular masses, and mountain masses, in primitive, transition, and secondary rocks in Great Britain, Germany, and other countries.

* Bog Iron-Ore.

Limonit. Fer Oxyde, des Lacs des Marais, &c.—*Raseneisenstein, Werner*.

Description.—Colour brown. Occurs massive, vesicular, corroded, amorphous, and tuberoso. Some varieties are friable. Lustre ranges from glistening to dull, and is semi-metallic-resinous. Fracture earthy or conchoidal. Opaque. Yields a yellowish-grey streak. Brittle, and easily frangible. Sp. gr. from 2.6 to 3.0.

Constituent Parts.—Oxide of iron 66.0, phosphoric acid 8.0, water 23.0, oxide of manganese 1.5. *Klaproth*.

Geognostic and Geographic Situations.—It occurs in alluvial soil and in peat-mosses in various places in the mainland of Scotland, and also in the Orkney, Shetland, and Western Islands.

4. Diprismatic Iron-Ore, or Lievrite.

Fer Calcareo-siliceux, *Haüy*.

Specific Character.—Pyramid = 139° 37'; 117° 38';

77° 16'. P + ∞ = 112° 37'. Cleavage Pr = 113° 2'; P + ∞; P — ∞; Pr + ∞. The whole, but particularly the first, imperfect. Streak black, sometimes inclining to green and brown. Does not affect the magnet. Hardness = 5.5,—6.0. Sp. gr. = 3.8,—4.1.

Description.—Colour black, blackish-green. Occurs regularly crystallized; also in distinct concretions, which are scopiform radiated, or straight radiated. Lustre glistening and semi-metallic. Fracture uneven. Opaque.

Constituent Parts.—Oxide of iron 52.24, silica 29.28, lime 13.78, oxide of manganese 1.58, water 1.27. *Stromeyer*.

Geognostic and Geographic Situations.—Occurs associated with epidote, garnet, magnetic iron-ore, and arsenic-pyrites, in limestone, in the island of Elba, and has also been found in Norway and West Greenland.

Genus XII.—MANGANESE-ORE.

Mangan-erz, Mohs.

Pyramidal. Prismatic. Streak dark-brown, black. Does not affect the magnet. Hardness = 2.0,—6.5. Sp. gr. = 4.0,—4.9. If streak brown, the sp. gr. = 4.7, and more; or hardness = 4.0, and less. If hardness above 4.0, sp. gr. = 4.2, and less; if the streak is black, it is shining.

1. Pyramidal Manganese-Ore, or Black Manganese-Ore. Hausmannite.

Pyramidales Mangan-erz, Mohs.—Schwarzer Braunstein, *Werner*.—Manganese oxydé hydraté, *Haüy*.

Specific Character.—Pyramidal. Pyramid = 105° 25'; 117° 54'. Cleavage P — ∞. Traces in the direction of P and P — 1 = 114° 51'; 99° 11'. Streak brown. Hardness = 5.0,—5.5. Sp. gr. = 4.7,—4.8.

Description.—Colour brownish-black. Occurs regularly crystallized; also massive, globular, in longish external forms. Lustre glimmering, glistening, and imperfect metallic. Fracture conchoidal and uneven. Opaque.

Constituent Parts.—Red oxide of manganese 98.10, oxygen 0.21, water 0.43, baryta 0.11, silica 0.34. *Turner*.

Geognostic and Geographic Situations.—Occurs in veins in porphyry, in Thuringia, the Hartz, and the United States.

2. Bractypous Manganese-Ore, or Braunite.

Specific Character.—Pyramidal. P = 109° 53'—108° 39'. Cleavage P, perfect. Streak black, slightly inclining to brown. Hardness = 6.0,—6.5. Sp. gr. = 4.8,—4.9.

Description.—Colour dark brownish-black. Occurs regularly crystallized; also massive. Lustre imperfect metallic and shining. Opaque. Streak black, inclining but slightly to brown. Fracture uneven. Brittle.

Constituent Parts.—Protoxide of manganese 86.94, oxygen 9.85, water 0.95, and baryta 2.26. *Turner*.

Geognostic and Geographic Situations.—Occurs in veins traversing porphyry, at Ochrenstock, near Ilmenau, also at St Marcel, in Piedmont.

Observations.—Named Braunite, in honour of Mr Braun of Gotha.

3. Uncleavable Manganese-Ore, or Psilomellane.

Untheilbares Mangan-erz, Mohs.—Schwartz-eisenstein, *Werner*.—Fasriger and Dichter Schwartz-braunstein, *Hausmann*.—Dichter Schwarz Mangan-erz, *Leonhard*.—Manganese Oxide-Hydraté Concretionné, *Haüy*.

Specific Character.—Reniform, botryoidal, massive, uncleavable. Streak brownish-black and shining. Hardness = 5.0,—6.0. Sp. gr. = 4.0,—4.2.

Description.—Colour black, passing into dark steel-grey. Occurs massive, in roundish and longish extended forms. Lustre imperfect metallic, shining or glimmering. Fracture compact and fibrous. Opaque.

Mineralogy.

Mineralogy.

Constituent Parts.—Red oxide of manganese 69.79, oxygen 7.36, baryta 16.36, silica 0.26, water 6.22. *Turner.*

Geognostic and Geographic Situations.—This ore of manganese occurs in veins and in nests in primitive, transition, and secondary rocks, very frequently associated with brown iron-ore and grey manganese-ore. In Devonshire and Cornwall, it occurs in botryoidal and stalactitic masses. It is one of the ores found at Ilfeld, in the Hartz, and is well known in other mining districts in Germany.

4. *Prismatoidal Manganese-Ore, or Grey Manganese-Ore.*

Prismatoidisches Mangan-erz, Mohs.—Grauer Brannstein, *Werner.*—Manganite, *Haidinger.*—Manganese oxydë, *Häuy.*

Specific Character.—Prismatoidal. Prismatic. $\bar{P}r = 114^\circ 19'$; $P + \infty = 99^\circ 40'$. Cleavage, $P + \infty$, very perfect. $P - \infty$, $P + \infty$, less perfect. Streak brown. Hardness = 3.5,—4.0. Sp. gr. = 4.3,—4.4.

Description.—Colour dark steel-grey, inclining to iron-black. Occurs regularly crystallized; in granular, fibrous, and radiated distinct concretions. Lustre shining, glimmering, and metallic. Fracture conchoidal and earthy. Brittle. Opaque.

Constituent Parts.—Red oxide of manganese 86.84, oxygen 3.05, water 10.10. *Turner.*

Geognostic and Geographic Situations.—Occurs in veins and imbedded masses in primitive, transition, and secondary rocks. Its chief locality in Scotland is the vicinity of Aberdeen. Occurs in different parts of England, and also in Ireland. The finest crystallized varieties are found at Ilfeld in the Hartz.

5. *Prismatic Manganese-Ore, or Pyrolusite.*

Prismatisches Mangan-erz, Mohs.—Anhydrous Peroxide of Manganese. *Turner.*

Specific Character.—Prismatic. $P + \infty = 93^\circ 40'$. Cleavage $P + \infty$, $\bar{P}r + \infty$, $P + \infty$. Streak black. Soils. Hardness = 2.0,—2.5. Sp. gr. = 4.6,—4.9.

Description.—Colour iron-black, sometimes inclining to bluish-black. Occurs massive, reniform. Lustre metallic. Opaque. Streak black. Soils.

Constituent Parts.—Red oxide of manganese 84.05, oxygen 11.78, water 1.12, baryta 0.53, silica 0.51. *Turner.*

Geognostic and Geographic Situations.—This valuable ore is extensively employed in the arts on account of the large quantity of oxygen it affords. Occurs in Devonshire and Cornwall, and is well known in the mines of Saxony, France, Hungary, and other countries.

Order IX.—NATIVE METAL.

Metallic. Not black. Hardness = 0.0,—5.0. Sp. gr. = 5.7,—20.0. If grey, it is sectile, and sp. gr. = 7.4, and more. If the hardness is above 4.0, it is malleable.

Genus I.—ARSENIC.

Rhombohedral. Colour tin-white. Hardness = 3.5. Sp. gr. = 5.7,—5.8.

1. *Rhombohedral Arsenic.*

Gediegen Arsenik, *Werner* and *Mohs.*—Arsenic natif, *Häuy.*

Specific Character.—Rhombohedral. Cleavage $R - \infty$.

Description.—Colour tin-white, which, on exposure, soon tarnishes to black. Occurs massive, in plates, reniform, botryoidal, reticulated, and with impressions. Lustre glistering, glimmering, and metallic. Fracture uneven. Emits, when struck, a ringing sound, and an arsenical odour.

Constituent Parts.—Arsenic 97.0, antimony 2.0, iron and water 1.0. *John.*

Geognostic and Geographic Situations.—It occurs in metalliferous veins, particularly where they cross each other, in gneiss, mica-slate, clay-slate, and porphyry; seldomer in

transition and secondary rocks; rarely in beds, and never in large quantity. The mines of Germany, Norway, France, and Russia, afford examples of this mineral.

Mineralogy.

Genus II.—TELLURIUM.

Rhombohedral. Tin-white. Hardness = 2.0,—2.5. Sp. gr. = 6.1,—6.2.

1. *Rhombohedral Tellurium.*

Gediegen silvan, *Werner.*—Gediegen tellur, *Hausmann.*—Tellur natif ferrifère et aurifère, *Häuy.*

Specific Character.—Rhombohedral. $R = 71^\circ 11'$. $P = 130^\circ 4'$; $115^\circ 12'$. Cleavage, $R - \infty$.

Description.—Colour tin-white. Occurs in granular distinct concretions, massive, and disseminated. Lustre shining and metallic. Rather brittle, and easily frangible. Streak unchanged.

Constituent Parts.—Tellurium 92.55, iron 7.20, gold 0.25. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in grey-wacke, in Transylvania.

Genus III.—ANTIMONY.

Rhombohedral. Prismatic. Colour white, but not inclining to red. Not malleable. Hardness = 3.0,—3.5. Sp. gr. = 6.5,—10.0.

1. *Rhombohedral Antimony, or Native Antimony.*

Rhomboedrisches Antimon, *Mohs.*—Gediegen Spiesglas, *Werner.*—Antimoine natif, *Häuy.*

Specific Character.—Rhombohedral. $R = 117^\circ 15'$. Cleavage $R - \infty$, very perfect; traces according to $R + 2$ and $P + \infty$. Hardness = 3.0,—3.5. Sp. gr. = 6.5,—6.8.

Description.—Colour tin-white. Occurs regularly crystallized; in granular and lamellar concretions; massive, disseminated, and reniform. Lustre splendid and metallic. Rather brittle.

Constituent Parts.—Consists of antimony, with small portions of iron, silver, and arsenic.

Geognostic and Geographic Situations.—Occurs in metalliferous veins in primitive rocks in Sweden, and in the mountains of Hanover, Dauphiny, Hungary, Brazil, and Mexico.

2. *Prismatic Antimony, or Antimonial Silver.*

Prismatisches Antimon, *Mohs.*—Spiesglas Silber, *Werner.*—Argent antimonial, *Häuy.*

Specific Character.—Prismatic. $P + \infty =$ nearly 120° . Cleavage, $P - \infty$. $\bar{P}r$. Less distinct $P + \infty$. (Fig. 27, 34, 30.) Hardness = 3.5. Sp. gr. = 8.9,—10.0.

Description.—Colour between silver and tin-white. Occurs regularly crystallized, and massive. Lustre splendid and metallic. Sectile.

Constituent Parts.—Silver 77.0, antimony 23.0. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in veins in primitive and transition rocks in Furstenberg, Salzburg, Hartz, and Spain.

Genus IV.—BISMUTH.

Tessular. Easily cleavable. Silver-white, inclining to red. Hardness = 2.0,—2.5. Sp. gr. = 9.6,—9.8.

1. *Octahedral Bismuth.*

Octaedrisches Wismuth, *Mohs.*—Gediegen Wismuth, *Werner.*—Bismuth natif, *Häuy.*

Specific Character.—Octahedral. Tessular. Combination semi-tessular, with inclined planes. Cleavage octohedral, perfect.

Description.—Colour silver-white. Occurs regularly crystallized; massive, disseminated, dentiform, and in leaves with a plumose streaked surface. Lustre splendid and metallic. Malleable.

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Constituent Parts.—It is the pure metal, sometimes containing a small quantity of arsenic.

Geognostic and Geographic Situations.—Occurs in veins in primitive rocks, as gneiss, granite, mica-slate, and clay-slate, in Cornwall, Germany, France, Norway, &c.

Genus V.—MERCURY.

Tessular, liquid. Not cleavable. Not malleable. White. Hardness = 0.0,—3.0. Sp. gr. = 10.5,—15.0.

1. *Liquid Native Mercury.*

Flüssiges Mercur, *Mohs.*—Gediegen Quecksilber, *Werner.*—Mercur Nativ, *Häuy.*

Specific Character.—Liquid. Colour tin-white. Hardness = 0. Sp. gr. = 12.0,—15.0.

Description.—Colour tin-white. Liquid. Splendent and metallic. Opaque.

Geognostic and Geographic Situations.—Rarely in primitive and transition rocks. More frequently in rocks of the secondary class, as sandstone. Deux-Ponts, Idria, and other European mining districts, afford examples of this metal.

2. *Dodecahedral Mercury, or Native Amalgam.*

Dodecaedrisches Mercur, *Mohs.*—Natürlich Amalgam, *Werner.*—Mercur Argent, *Häuy.*

Specific Character.—Tessular. Silver-white. Hardness = 1.0,—3.0. Sp. gr. = 10.5,—14.0.

Description.—Colour silver-white. Occurs regularly crystallized. Lustre shining and metallic. Fracture uneven. When pressed between the fingers, or cut with a knife, it emits a creaking sound, like artificial amalgam.

Geognostic and Geographic Situations.—Occurs in Deux-Ponts, and other mercury mines, along with cinnabar.

Genus VI.—SILVER.

Tessular. Uncleavable. Silver-white. Malleable. Hardness = 2.5,—3.0. Sp. gr. 10.0,—11.0.

1. *Hexahedral Silver.*

Hexaedrisches, Silber, *Mohs.*—Argent Nativ, *Häuy.*

Specific Character.—Tessular. No cleavage.

Description.—Colour silver-white, and silver-white inclining to brass-yellow. Occurs regularly crystallized, massive, disseminated, dentiform, filiform, reticulated, and in leaves. Lustre metallic, and ranges from splendent to glimmering. Fracture hackly. Opaque.

The yellow varieties are named *auriferous native silver*, from their containing a portion of gold; the other varieties *common native silver*.

Geognostic and Geographic Situations.—Common native silver occurs in veins, generally occupying their middle or upper parts; and those veins traverse granite, gneiss, mica-slate, clay-slate, hornblende-slate, syenite, and porphyry, in primitive mountains, and greywacke in transition mountains. It rarely occurs in secondary rocks, as in sandstone. The mines of Cornwall, Saxony, Hungary, Mexico, afford this mineral in all its forms. The auriferous native silver was formerly found in the mines of Königsberg in Norway; and, at present, in those of Schlangenberg in Siberia.

Genus VII.—GOLD.

Tessular. Gold-yellow. Hardness 2.5,—3.0. Sp. gr. = 12.0,—20.0.

1. *Hexahedral Gold.*

Hexaedrisches Gediegen Gold, *Mohs.*—Gediegen Gold, *Werner.*—Or natif, *Häuy.*

Specific Character.—Tessular. No cleavage.

Description.—Colours gold-yellow and brass-yellow. Occurs regularly crystallized, massive, disseminated, in flakes, in leaves, reticulated, capillary, dentiform, and in grains. Lustre shining, glistening, and metallic. Fracture hackly. Opaque.

The gold-yellow varieties are named *gold-yellow gold*; the brass-yellow varieties, *brass-yellow gold*; those varieties in which the brass-yellow verges on steel-grey, are named *greyish-yellow gold*; and, lastly, the pale brass-yellow, inclining to silver-white, varieties, are named *electrum* or *argentiferous gold*.

Geognostic and Geographic Situations.—Occurs in veins, and disseminated in granite, syenite, gneiss, mica-slate, hornblende-slate, porphyry, greywacke, clay-slate, &c.; also in various alluvial deposits. The mines of Germany, Hungary, and America, afford examples of the various mineralogical and geological relations of this important mineral.

Genus VIII.—IRIDIUM.

Rhombohedral. Easily cleavable. Colour pale steel-grey. Ductile. Hardness = 4.5,—5.0. Sp. gr. = 11.5,—12.5.

1. *Rhombohedral Iridium.*

Rhomboedrisches Iridium, *Mohs.*—Osmium-Iridium, *Leonhard.*—Iridium Osmie, *Häuy.*

Specific Character.—Rhombohedral. Cleavage R — ∞, perfect.

Description.—Colour pale steel-grey. Occurs in grains, rarely in six-sided prisms. Lustre metallic. Cleavage easily obtained. Opaque.

Constituent Parts.—Osmium 24.5, iridium 72.9, iron 2.6. *Thomson.*

Geognostic and Geographic Situations.—It occurs along with platina in the province of Choco in South America. It is found also in the Uralian Mountains.

Genus IX.—PALLADIUM.

Tessular. Colour steel-grey. Ductile. Hardness = 4.5,—5.0. Sp. gr. = 11.5,—12.5.

1. *Octahedral Palladium.*

Octaedrisches Palladium, *Mohs.*

Specific Character.—Tessular. Uncleavable.

Description.—Colour steel-grey. Occurs in grains. Lustre metallic. Ductile, and very malleable.

Geognostic and Geographic Situations.—Occurs along with platina and iridium in Minas Geras, in Brazil.

Genus X.—PLATINA.

Tessular. Uncleavable. Colour steel-grey. Ductile. Hardness = 4.0,—4.5. Sp. gr. = 16.0,—20.0.

1. *Hexahedral Platina.*

Gediegen Platin, *Werner.*—Hexaedrisches Platina, *Mohs.*—Platin natif, *Häuy.*

Specific Character.—Tessular. In grains.

Description.—Colour steel-grey. Occurs in small flat or angular grains, seldomer in blunt-edged pieces. Lustre metallic, and shining. Fracture hackly. No cleavage, Ductile.

Constituent Parts.—Grains from Columbia. Platina 84.30, rhodium 3.46, palladium 1.06, iridium 1.46, osmium 1.03, copper 0.74, iron 5.31. *Berzelius.*

Geognostic and Geographic Situations.—It occurs in blunt-edged pieces and grains along with iridium, palladium, gold, magnetic iron-sand, &c. in the alluvial deposits of Brazil, Choco, and Barbaco in South America. It also occurs, and rather abundantly, at Joetsk in the Government of Perm in Siberia.

Genus XI.—IRON.

Tessular. Colour pale steel-grey. Hardness 4.5. Sp. gr. = 7.4,—7.8.

1. *Octahedral Iron.*

Octaedrisches Eisen, *Mohs.*—Gediegen Eisen, *Werner.*—Fer natif, *Häuy.*

Specific Character.—Tessular. No cleavage.

Description.—Colour pale steel-grey. Occurs ramose,

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and disseminated in meteoric stones. Lustre glimmering, glistening, and metallic. Fracture hackly.

Constituent Parts.—1. *Atacama*. Iron 93.40, nickel 6.62, cobalt 0.53. *Turner*.—2. *Siberia*. Iron 98.5, nickel 1.5. *Klaproth*.—3. *Agram*. Iron 96.5, nickel 3.5. *Klaproth*.

Geognostic and Geographic Situations.—It is a meteoric production, and has been observed to fall from fireballs in Europe, Asia, and America.

Genus XII.—COPPER.

Tessular. Colour copper-red. Hardness = 2.5,—3.0. Sp. gr. = 8.4,—8.9.

1. *Octahedral Copper*.

Octaedrisches Kupfer, *Mohs*.—Gediegen Kupfer, *Werner*.—Cuivre natif, *Haüy*.

Specific Character.—Tessular. No cleavage.

Description.—Colour copper-red. Occurs regularly crystallized; massive, dendritic, capillary, botryoidal, and ramose. Lustre glistening and metallic. Fracture hackly. Ductile. Streak shining and unchanged.

Geognostic and Geographic Situations.—Occurs in granite, gneiss, mica-slate, clay-slate, primitive limestone, syenite, serpentine, greywacke, secondary limestone, sandstone, and generally in small veins; also in grains, and sometimes in blocks many pounds weight, in alluvial districts. It occurs in serpentine in Shetland, and in the copper mines of Cornwall. Large masses are met with in alluvial districts in the northern parts of North America.

Order X.—PYRITES.

Metallic. Streak black. Hardness = 3.0,—6.5. Sp. gr. = 4.1,—7.7. If hardness = 4.5 and less, the sp. gr. is less than 5.3. If sp. gr. = 5.3 and less, the colour is yellow or red.

Genus I.—NICKEL PYRITES, or COPPER-NICKEL.

Prismatic. Colour copper-red. Hardness = 5.0,—5.5. Sp. gr. = 7.5,—7.7.

1. *Prismatic Nickel Pyrites*.

Prismatischer Nickel-kies, *Mohs*.—Kupfer-Nickel, *Werner*.—Nickel Arsenical, *Haüy*.

Specific Character.—Prismatic. Cleavage very imperfect.

Description.—Colour copper-red. Rarely crystallized; in granular distinct concretions; massive, disseminated, reticulated, dendritic, fruticose, globular, and botryoidal. Lustre shining and metallic. Fracture conchoidal. Brittle.

Constituent Parts.—Nickel 44.21, arsenic 54.73. *Stromeyer*.

Geognostic and Geographic Situations.—Occurs in silver and cobalt veins in gneiss, mica-slate, clay-slate, and syenite; also in veins in secondary rocks, particularly bituminous marl-slate. In Scotland it is met with at Leadhills and Wanlockhead, and in the coal-field of West Lothian.

* *Nickel Ochre.*—Colour apple-green. Occurs as a thin coating, seldom massive, and disseminated. Dull. Fracture uneven or earthy. Opaque, or translucent on the edges. Soft. Feels meagre. It occurs in mineral veins along with copper-nickel at Alva in Stirlingshire, in Linlithgowshire, and at Leadhills.

** *Black Nickel.*—Colour black. Occurs massive, disseminated, in crusts. Dull. Fracture earthy. Opaque. Soft. Shining in streak. Soils slightly. It occurs in veins in bituminous marl-slate at Reichelsdorf.

Genus II.—ARSENIC PYRITES.

Prismatic. Colour not inclining to red. Hardness = 5.0,—6.0. Sp. gr. = 5.7,—7.4. If colour white or grey, the sp. gr. under 6.3, or above 7.0.

1. *Axotomous Arsenic Pyrites*.

Axotomer Arsenik-kies, *Mohs*.—Arsenik-kies, *Werner*.

Specific Character.—Prismatic. $\bar{P}r = 51^\circ 20'$. $P + \infty$

$= 122^\circ 26'$. Cleavage $P - \infty$, perfect. Less $\bar{P}r = 86^\circ 10'$. Traces in direction of $P + \infty$. (Fig. 27, 30). Hardness = 5.0,—5.5. Sp. gr. = 7.1,—7.4.

Description.—Colour pale steel-grey. Occurs massive. Lustre metallic and shining. Streak greyish-black. Fracture uneven. Brittle.

Constituent Parts.—It is a compound of arsenic and iron.

Geognostic and Geographic Situations.—Occurs with copper-nickel in Styria, with serpentine in Silesia, and also in Hungary.

2. *Prismatic Arsenic Pyrites*.

Prismatischer Arsenik-kies, *Mohs*.—Arsenik-kies, *Werner*.—Fer Arsenical, *Haüy*.

Specific Character.—Prismatic. $\bar{P}r - 1 = 145^\circ 26'$; $P + \infty$, $111^\circ 53'$. Cleavage $P - \infty$. ($\bar{P}r + \infty$)³ $111^\circ 19'$. (Fig. 27, 32.) Hardness = 5.5,—6.0. Sp. gr. = 5.7,—6.2.

Description.—Colour silver-white, inclining to steel-grey. Occurs regularly crystallized; in prismatic concretions, massive and disseminated. Lustre ranges from splendid to glistening, and is metallic. Fracture uneven. Opaque. Brittle. Streak greyish-black.

Constituent Parts.—Iron 36.04, arsenic 42.88, sulphur 22.08. *Stromeyer*.

Geognostic and Geographic Situations.—This mineral occurs in a variety of metalliferous formations in primitive mountains, and also in those of the transition and secondary classes. In Scotland it occurs in secondary rocks in Stirlingshire, and in considerable quantity in the mines of Devon and Cornwall.

Genus III.—COBALT PYRITES.

Tessular. Colour white, inclining to steel-grey or red. Hardness = 5.0,—5.5. Sp. gr. = 6.0,—6.6.

1. *Hexahedral Cobalt Pyrites, or Silver White Cobalt*.

Hexaedrisches Kobalt-kies, *Mohs*.—Glanz Kobold, *Werner*.—Cobalt gris, *Haüy*.

Specific Character.—Tessular. Combination semi-tessular, of parallel faces. Cleavage hexahedral and perfect. Colour white, inclining to red. Hardness = 5.5. Sp. gr. = 6.1,—6.35.

Description.—Colour silver-white, inclining to copper-red. Occurs regularly crystallized; in granular distinct concretions, massive, disseminated, and reticulated. Lustre shining, glistening, and metallic. Fracture uneven or conchoidal. Brittle. Easily frangible. Streak greyish-black.

Constituent Parts.—From *Modum*. Cobalt 33.10, arsenic 43.46, iron 2.23, sulphur 20.08. *Stromeyer*.

Geognostic and Geographic Situations.—Occurs in beds, in mica-slate, associated with iron and copper-pyrites, magnetic iron-ore, anthophyllite, tourmaline, felspar, &c. in the parish of Modum, in Norway, also at Tunaberg, in Sweden. In some transition districts it is found in veins along with various ores of iron and copper.

2. *Octahedral Cobalt-Pyrites, or Tin-White Cobalt*.

Octaedrischer Cobalt-kies, *Mohs*.—Weisser Speis-kobald, *Werner*.—Cobalt Arsenical, *Haüy*.

Specific Character.—Tessular. Cleavage hexahedral, octahedral, dodecahedral, but indistinct. Tin-white, inclining to steel-grey. Hardness = 5.5. Sp. gr. = 6.4,—6.6.

Description.—Colour tin-white, inclining to steel-grey. Occurs regularly crystallized, and the faces of the crystals frequently cracked; in lamellar and granular concretions; massive, disseminated, reticulated, fruticose, specular. Lustre shining, splendid, and metallic. Fracture uneven. Brittle and easily frangible. Streak greyish-black.

Constituent Parts.—*Reichelsdorf*. Cobalt 20.31, arsenic 74.21, iron 3.42, copper 0.15, sulphur 0.88. *Stromeyer*.

Geognostic and Geographic Situations.—Occurs in veins in primitive and transition rocks; also in old red sandstone

Mineralogy.

Mineralogy. and in copper-slate. Cornwall, Hessa, Thuringia, Hartz, &c. afford many localities of this mineral.

3. Isometric Cobalt-Pyrites.

Isometrischer Cobalt-Kies, *Mohs*.—Cobalt-Kies, *Hausmann*.

Specific Character.—Tessular. Cleavage hexahedral, perfect. Colour white, inclining to red. Hardness = 5.5. Sp. gr. = 6.3,—6.4.

Description.—Colour white, inclining to red. Occurs massive, in granular concretions, and in cubo-octahedral crystals. Lustre metallic. Fracture uneven or imperfect conchoidal.

Constituent Parts.—*Musen, in Nausau Siegen*. Cobalt 53.35, sulphur 42.25, iron 2.30, copper 0.97. *Wernekinck*.—2. *Ridderhyttan, Sweden*. Cobalt 43.20, copper 14.40, iron 3.53, sulphur 38.50. *Hisinger*.

Geognostic and Geographic Situations.—Occurs in gneiss, associated with hornblende and copper-pyrites at Bastnais, near Ridderhyttan, in Sweden, and at Musen, near Siegen, with heavy spar and sparry iron.

4. Eutomous Cobalt-Pyrites, or Nickeliferous Cobalt-Pyrites.

Eutomer Kobalt-kies, *Mohs*.—Nickelspiesglasserz, *Hausmann*.—Nickel Arsenical Antimonifere, *Haüy*.

Specific Character.—Tessular. Cleavage hexahedral, perfect. Colour pale steel-grey. Hardness = 5.0,—5.5. Sp. gr. = 6.4,—6.5.

Description.—Colour pale steel-grey, sometimes on exposure becoming blackish. Colour of the streak darker. Occurs massive, disseminated, and in cubo-octahedral crystals, and in granular concretions. Lustre metallic. Fracture uneven. Brittle.

Constituent Parts.—Nickel 36.60, antimony 43.80, sulphur 17.71, iron and manganese 1.89. *Stromeyer*.

Geognostic and Geographic Situations.—Occurs in veins of ironstone and lead-glance, in transition rocks along with sparry iron, cobalt-pyrites, grey copper, and copper-pyrites, in Nassau Siegen in the Westerwald.

Genus IV.—IRON-PYRITES.

Tessular, rhombohedral, prismatic, Yellow, partly inclining to copper-red. Hardness = 3.5,—6.5. Sp. gr. = 4.4,—5.05.

1. Hexahedral Iron-Pyrites.

Hexaedrischer Eisen-Kies, *Mohs*.—Gemeiner Schwefel-Kies, *Werner*.—Fer Sulphuré, *Haüy*.

Specific Character.—Tessular. Combination semi-tessular of parallel planes. Cleavage hexahedral and octahedral. Bronze-yellow. Hardness = 6.0,—6.5. Sp. gr. = 4.9,—5.05.

Description.—Colour bronze-yellow, sometimes inclining to steel-grey. Occurs regularly crystallized in various tessular forms; in granular concretions; massive, disseminated, globular, and cellular. Lustre ranges from shining to glimmering, and is metallic. Fracture uneven and conchoidal. Opaque. Brittle.

Constituent Parts.—Iron 47.85, sulphur 52.15. *Hatchett*.

Geognostic and Geographic Situations.—The cellular varieties are rare, and hitherto have been met with principally in Saxony; while the others occur in all countries, and more or less extensively distributed through rocks of every description, from those of the oldest primitive, to the newest alluvial formations.

2. Prismatic Iron-Pyrites or Radiated Iron-Pyrites.

Prismatischer Eisenkies, *Mohs*.—Fer Sulphuré Blanc, *Haüy*.—Wasser-Kies. Strahl-Kies. Kam-kies. Leber-Kies. Spär-Kies. Zell-Kies.

Specific Character.—Prismatic. $\text{Pr} = 114^\circ 19'$. $\text{Pr} = 106^\circ 36'$. $\text{P} + \infty = 98^\circ 13'$. Cleavage Pr , traces according to $\text{P} + \infty$. (Fig. 30.) Colour bronze-yellow. Hardness = 6.0,—6.5. Sp. gr. = 4.65,—4.9.

Description.—Colour bronze-yellow, inclining sometimes to steel-grey, or to brass-yellow. Occurs regularly crystallized; in radiated, granular, and lamellar concretions; massive, dendritic, reniform, globular, stalactitic, botryoidal, fruticose, and with impressions. Lustre varies from glistening to glimmering, and is metallic. Opaque. Brittle. Easily frangible.

The varieties in radiated concretions are named *radiated-pyrites*; those in which the colour inclines to brass-yellow, and which, on exposure to air, acquire a brown tarnish, are named *hepatic-pyrites*; those in spear-shaped twin and triple crystals, *spear-pyrites*; and lastly, those in which the crystals are so aggregated as to have the form of the comb of the cock, are named *cockscomb-pyrites*.

Constituent Parts.—Iron 45.66, sulphur 54.34. *Hatchett*.

Geognostic and Geographic Situations.—This species of iron-pyrites occurs more frequently and abundantly in newer than in older formations. The newest secondary formations, and those of the alluvial class, both in this island and on the continent of Europe, afford numerous localities of the radiated varieties. The spear-pyrites is met with in Bohemia and Saxony; and the cockscomb-pyrites in veins in Derbyshire, and in some ruins in Saxony.

3. Rhombohedral Iron-Pyrites, or Magnetic-Pyrites.

Rhomboedrischer Eisenkies, *Mohs*.—Magnetkies, *Werner*.—Fer Sulphuré Ferrifère, *Haüy*.

Specific Character.—Rhombohedral. Rhombohedron unknown. Combination di-rhombohedral. Cleavage, $\text{P} = \infty$, perfect. Less distinct $\text{P} + \infty$. Colour bronze-yellow, inclining to copper-red. Hardness = 3.5,—4.5. Sp. gr. 4.4,—4.7.

Description.—Colours intermediate between bronze-yellow and copper-red. Occurs rarely crystallized; in granular concretions, also massive and disseminated. Lustre ranges from splendid to glistening, and is metallic. Fracture conchoidal and uneven. Opaque. Brittle. Easily frangible.

Constituent Parts.—Iron 63.5, sulphur 36.5. *Hatchett*.

Geognostic and Geographic Situations.—This mineral occurs disseminated in primitive and transition rocks, and also disposed in beds in rocks of the same classes, in Scotland, England, Saxony, &c.

Genus V.—COPPER-PYRITES.

Tessular. Pyramidal. Hardness = 3.0,—4.0. Sp. gr. = 4.1,—5.1.

1. Pyramidal Copper-Pyrites, or Yellow Copper-Pyrites.

Pyramidaler Kupfer-kies, *Mohs*.—Kupfer-kies, *Werner*.—Cuivre pyriteux, *Haüy*.

Specific Character.—Pyramidal. Pyramid $109^\circ 53'$; $108^\circ 40'$. Combination hemi-pyramidal, of inclined planes. Cleavage, $\text{P} + 1 = 101^\circ 49'$; $126^\circ 11'$. Colour brass-yellow. Hardness = 3.5,—4.0. Sp. gr. = 4.1,—4.3.

Constituent Parts.—Copper 33.12, iron 30.00, sulphur 36.52, silica 0.39. *Rose*.

Geognostic and Geographic Situations.—This species of pyrites is found in all the great classes of rocks, not only in veins, but also in beds, and in vast imbedded masses. The copper-mines in England afford it in great variety and abundance; it occurs also in Scotland, but in smaller quantities.

2. Octahedral Copper-Pyrites, or Variegated Copper.

Bunt Kupfererz, *Werner*.—Cuivre-Pyriteux-hepatique, *Haüy*.

Specific Character.—Tessular. Cleavage octahedral, very imperfect. Colour copper-red. Hardness = 3.0. Sp. gr. = 4.9,—5.1.

Description.—Colour between copper-red and pinchbeck-brown, but soon acquires a variegated tarnish. Occurs in cubes truncated on the angles; also massive. Lustre shining and metallic. Fracture conchoidal.

Mineralogy.

Constituent Parts.—From Killarney. Copper 61.07, sulphur 23.75, iron 14.00, silica 0.50. *Phillips.*

Geognostic and Geographic Situations.—Occurs in primitive, transition, and secondary rocks. The finest British specimens are from the coppermines of Cornwall. Ross Island in Killarney in Ireland, also affords this ore, as do copper mines in Norway, Hessia, Silesia, the Bannat, and Siberia.

Order XI.—GLANCE.

Metallic. Colour and streak grey, black. Hardness = 1.0,—4.0. Sp. gr. = 4.2,—7.6. If cleavage monotonous, and sp. gr. below 5.0, the colour is lead-grey. If hardness = 2.5 and less, the sp. gr. is above 5.0, or the colour is lead-grey. If the sp. gr. is above 7.4, the colour is lead-grey.

Genus I.—COPPER-GLANCE.

Tessular, prismatic. Colour blackish lead-grey; steel-grey, sometimes inclining to yellow; black. Cleavage imperfect, not axotomous. Hardness = 2.5,—4.0. Sp. gr. = 4.3,—5.8.

1. Tetrahedral Copper-Glance.

Tetradrischer Kupfer-Glanz, *Mohs.*—Fahlerz. Schwarz-erz, *Werner.*—Cuivre gris, *Häuy.*

Specific Character.—Tessular. Combination semi-tessular of inclined planes. Cleavage octahedral. Colour steel-grey,...iron-black. Hardness = 3.0,—4.0. Sp. gr. = 4.5,—5.2.

Description.—Colour steel-grey, and iron-black. Occurs regularly crystallized, massive, and disseminated. Lustre externally splendid and metallic, internally shining, or glistening, and metallic. Fracture conchoidal or uneven. Opaque, brittle, and easily frangible.

The grey varieties are named *grey copper*; the black, *black copper*.

Constituent Parts.—*Fahlerz.* Copper 48.0, arsenic 14.0, sulphur 10.0, iron 25.5, silver 0.5. *Klaproth.* *Schwartz-erz.* Copper 40.25, arsenic 0.75, antimony 23.00, sulphur 18.50, iron 13.50, silver 0.30. *Klaproth.*

Geognostic and Geographic Situations.—The grey varieties occur in veins in transition granite, and syenite, at Fassney Burn, in East Lothian; at Airthrie, in Stirlingshire; in Ayrshire, and in Devonshire. The black varieties are found in transition rocks, at Clausthal in the Hartz.

2. Prismatic Copper-Glance.

Prismatoidischer Kupfer-glanz, *Mohs.*

Specific Character.—Prismatic. Pyramid unknown.

Cleavage, $\text{Pr} + \infty$. (Fig. 29.) Colour blackish lead-grey. Brittle. Hardness = 3.0. Sp. gr. = 5.7,—5.8.

Description.—Colour blackish lead-grey. Crystals in oblique four-sided prisms. Lustre shining and metallic.

Geognostic and Geographic Situations.—Occurs along with sparry iron at St Gertraud, near Wolfsberg, in the valley of Lavan, in Carinthia.

3. Prismatic Copper-Glance, or Vitreous Copper.

Prismatischer Kupfer-Glanz, *Mohs.*—Kupferglas, *Werner.*—Cuivre Sulphuré, *Häuy.*

Specific Character.—Prismatic. $\text{Pr} = 119^\circ 35'$. $(\text{P} + \infty)^2 = 63^\circ 48'$. Cleavage Pr . Colour blackish lead-grey. Very sectile. Hardness = 2.5,—3.0. Sp. gr. = 5.5,—5.8.

Description.—Colour blackish lead-grey. Occurs regularly crystallized, also in granular concretions, and massive. Lustre glistening, glimmering and metallic. Fracture conchoidal and uneven. Opaque. Sectile.

Constituent Parts.—Copper 84.0, sulphur 12.0, iron 4.0. *Chenevix.*

Geognostic and Geographic Situations.—Occurs in veins at Fassney Burn; in the rocks of Fair Isle; in Yorkshire, Caernarvonshire, and Cornwall.

4. Diprismatic Copper-Glance, or Bournonite.

Schwarz-Spiesglaserz, *Werner.*—Diprismatischer Kupfer-Glanz, *Mohs.*—Plomb Sulphure Antimonifère, and Antimoine Sulphuré Plombo-Cuprifère, *Häuy.*—Endellione.

Specific Character.—Prismatic. $\text{Pr} = 93^\circ 40'$; $\text{Pr} - 1 = 87^\circ 8'$; $(\text{P} + \infty)^2 = 96^\circ 31'$. Cleavage $\text{Pr} + \infty$; $\text{Pr} + \infty$. First the more perfect of the two. Colour steel-grey, inclining to lead-grey or iron-black. Brittle. Hardness = 2.5,—3.0. Sp. gr. = 5.7,—5.8.

Description.—Colour steel-grey, inclining to lead-grey, or iron-black. Occurs massive and regularly crystallized. Lustre splendid and metallic. Fracture conchoidal or uneven. Opaque. Streak unchanged. Brittle and very easily frangible.

Constituent Parts.—From Endellion. Lead 42.62, antimony 24.23, copper 12.80, iron 1.20, sulphur 17.00. *Hatchett.*

Geognostic and Geographic Situations.—The finest specimens of this mineral are found in the mines of Neudorf, in the Hartz; it was, we believe, first found in the parish of Endellion, near Redruth, in Cornwall, and was described by Bournon under the name Endellionite, but we, in compliment to Bournon, named it Bournonite.

5. Hexahedral Copper-Glance.

Zinnkies, *Werner.*—Hexadrischer Kupfer-Glanze, *Mohs.*

Specific Character.—Tessular. Cleavage hexahedral, dodecahedral. Colour steel-grey, inclining to brass-yellow. Brittle. Hardness = 4.0. Sp. gr. = 4.3,—4.4.

Description.—Colour steel-grey, inclining more or less to brass-yellow. Streak black. Occurs massive and crystallized in cubes. Lustre metallic. Fracture uneven. Brittle. Opaque.

Constituent Parts.—Tin 24.0, copper 36.0, iron 2.0, sulphur 25.0. *Klaproth.*

Geognostic and Geographic Situations.—It has hitherto been found only in metalliferous veins in Cornwall, principally at Huel Rock, in the parish of St Agnes, where it is associated with blende, copper-pyrites, and other minerals.

* Tennantite, *Phillips.*

Description.—Colour blackish lead-grey. Streak dark-reddish grey. Tessular. Cleavage dodecahedral, but imperfect. Lustre metallic. Fracture uneven. Brittle. Hardness = 4.0. Sp. gr. = 4.3,—4.4.

Constituent Parts.—Copper 45.32, arsenic 11.84, iron 9.26, sulphur 28.74, silica 5.00. *Phillips.*

Geognostic and Geographic Situations.—Hitherto this mineral has been found only in Cornwall, where it occurs in copper veins, that traverse granite and clay-slate, in the mines near Redruth and St Day.

Genus II.—SILVER-GLANCE, or VITREOUS SILVER.

Silber-Glanz, *Mohs.*

Tessular. Blackish lead-grey. Hardness = 2.0,—2.5. Sp. gr. = 6.9,—7.2.

1. Hexahedral Silver-Glance.

Hexadrischer Silber-glanz, *Mohs.*—Glaserz, *Werner.*—Argent Sulphuré, *Häuy.*

Specific Character.—Tessular. Cleavage dodecahedral, but very imperfect. Malleable.

Description.—Colour blackish lead-grey. Occurs regularly crystallized, most frequently in cubo-octahedrons; massive, disseminated, in plates, dentiform, filiform, capillary, reticulated, dendritic, stalactitic, and with impressions. Lustre shining, glistening, and metallic. Fracture uneven or conchoidal. Completely malleable. Flexible, but not elastic.

Constituent Parts.—Silver 85.0, sulphur 15.0. *Klaproth.*

Geognostic and Geographic Situations.—It is one of the most common of the ores of silver. It was formerly met

Mineralogy.

Mineralogy. with at Airthrie in Stirlingshire, and is still found in the mines of Cornwall.

Genus III.—GALENA, or LEAD-GLANCE.

Tessular. Colour pure lead-grey. Hardness = 2.5. Sp. gr. = 7.4,—7.6.

1. Hexahedral Galena, or Lead-Glance.

Hexaedrischer Bleiglanz, *Mohs*.—Bleiglanz, *Werner*.—Plomb Sulphuré, *Haüy*.

Specific Character.—Tessular. Cleavage hexahedral, perfect.

Description.—Colour lead-grey. Occurs regularly crystallized, frequently in cubes and cubo-octahedrons; in granular, prismatic, and lamellar concretions; massive, disseminated, specular, reticulated, botryoidal, and corroded. Lustre splendid to glimmering and metallic. Fracture even, or flat conchoidal. Fragments cubical. Sectile. Uncommonly easily frangible.

The variety with glimmering lustre, and even or conchoidal fracture, is named *compact galena*.

Constituent Parts.—Lead 85.13, sulphur 13.02. *Thomson*. A good series of analysis of this ore much wanted.

Geognostic and Geographic Situations.—This mineral, the species from which all the lead of commerce is obtained, occurs in every lead mine, whether in primitive, transition, or secondary rocks.

Genus IV.—TELLURIUM-GLANCE, or BLACK TELLURIUM.

Tellur-Glanz, *Mohs*.

Pyramidal. Colour blackish lead-grey. Cleavage monotomous, perfect. Hardness = 1.0,—1.5. Sp. gr. = 7.0,—7.2.

1. Pyramidal Tellurium-Glance.

Pyramidaler Tellur-Glanz, *Mohs*.—Nagyagerz, *Werner*.—Tellure Natif Auro-Plombifère, *Haüy*.

Specific Character.—Pyramidal. $P = 96^\circ 43'$; $140^\circ 0'$. Cleavage $P - \infty$. Blackish lead-grey.

Description.—Colour blackish lead-grey. Occurs regularly crystallized; massive, disseminated, and in leaves. Lustre splendid and metallic. Sectile. Folia flexible.

Constituent Parts.—Tellurium 32.2, lead 54.0, gold 9.0, silver 0.7, copper 1.3, sulphur 3.0. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in veins that traverse porphyry, in Transylvania.

Genus V.—MOLYBDENA, or MOLYBDENA-GLANCE.

Molybdän-Glanz, *Mohs*.

Rhombohedral. Colour pure lead-grey. In thin leaves, easily flexible. Hardness = 1.0,—1.5. Sp. gr. = 4.4,—4.6.

1. Rhombohedral Molybdena.

Rhomboedrischer Molybdän, *Mohs*.—Wasserblei, *Werner*.—Molybdene Sulphuré, *Haüy*.

Specific Character.—Rhombohedral. Combination di-rhombohedral. Cleavage $R - \infty$, very perfect.

Description.—Colour fresh lead-grey. Occurs regularly crystallized; massive, disseminated, and in plates; in granular concretions. Lustre splendid or shining and metallic. Sectile, approaching to malleable.

Constituent Parts.—Molybdena 60.0, sulphur 40.0. *Bucholz*.

Geognostic and Geographic Situations.—Occurs imbedded in granite and syenite at Peterhead; in chlorite-slate in Glenelg; in granite and syenite in Corybug, at the head of Loch Creran, and in various mines in Cornwall.

* Molybdena Ochre.

The sulphur-yellow mineral which sometimes incrusts molybdena is named *molybdena ochre*.

Genus VI.—BISMUTH-GLANCE.

Prismatic. Colour pure lead-grey. Hardness = 2.0,—2.5. Sp. gr. = 6.1,—6.4.

1. Prismatic Bismuth-Glance.

Prismatischer Wismuth-Glanz, *Mohs*.—Wismuth-Glanz, *Werner*.—Bismuth sulphuré, *Haüy*.

Specific Character.—Prismatic. Pyramid unknown. Cleavage $P - \infty$; $P + \infty$, imperfect. $\bar{P}r + \infty$. $\bar{P}r + \infty$, larger, more perfect. (Fig. 30, 29, 28.)

Description.—Colour pale lead-grey. Occurs regularly crystallized; in granular and radiated concretions; massive and disseminated. Internally splendid and metallic. Fracture foliated or fibrous. Soils. Streak unchanged. Brittle, inclining to sectile. Easily frangible.

Constituent Parts.—Bismuth 80.98, sulphur 18.72. *Rose*.

Geognostic and Geographic Situations.—Occurs in veins in Cornwall; associated with molybdena and apatite at Caldbeck Fell, in Cumberland.

* Bismuth-Ochre.

Wismuth-ocker, *Werner*.

The yellow, grey, or green mineral which sometimes accompanies bismuth-glance, is the bismuth ochre of mineralogists.

Genus VII.—ANTIMONY-GLANCE.

Antimon-Glanz, *Mohs*.

Prismatic. Colour lead-grey, not blackish; steel-grey. Cleavage perfect. Hardness = 1.5,—2.5. Sp. gr. = 4.2,—5.8. If the specific gravity is less than 5.3, the hardness = 2.0; easily broken when in thin plates. If sp. gr. is above 5.3, the colour is steel-grey.

1. Prismatic Antimony-Glance, or Graphical Tellurium.

Prismatischer Antimon-glanz, *Mohs*.—Schrift-erz, *Werner*.—Tellure natif auro-argentifère, *Haüy*.

Specific Character.—Prismatic. $P + \infty = 94^\circ 20'$. Cleavage $\bar{P}r + \infty$, perfect. Less distinct $\bar{P}r + \infty$. (Fig. 29, 28.) Colour pure steel-grey. Hardness = 1.5,—2.0. Sp. gr. = 5.7,—5.8.

Description.—Colour steel-grey. Occurs regularly crystallized; massive, disseminated, and in leaves. Externally splendid, internally glistening, and metallic. Fracture uneven. Sectile.

Constituent Parts.—Tellurium 61.35, gold 28.36, silver 10.29. *Klaproth*.

Geognostic and Geographic Situations.—Occurs in porphyry veins in Transylvania.

2. Prismatoidal Antimony-Glance, or Grey Antimony.

Grau Spiesglaserz, *Werner*.—Prismatoidischer Antimon-Glanz, *Mohs*.—Antimoine sulphuré, *Haüy*.

Specific Character.—Prismatic. $P = 109^\circ 16'$; $108^\circ 10'$; $110^\circ 59'$. $P + \infty = 90^\circ 45'$. Cleavage $\bar{P}r + \infty$, perfect. Less distinct, $P - \infty$. $P + \infty$. $\bar{P}r + \infty$. (Fig. 29, 27, 30, 28.) Lead-grey. Hardness = 2.0. Sp. gr. = 4.2,—4.7.

Description.—Colour lead-grey. Occurs regularly crystallized; in radiated, fibrous, and granular distinct concretions. Lustre ranges from glistening to splendid, and is metallic. Fracture even and uneven. Rather brittle, and easily frangible.

Constituent Parts.—Antimony 74.06, sulphur 25.94. *Davy*.

Geognostic and Geographic Situations.—Occurs in veins that traverse greywacke, at Westerhall, in Dumfriesshire, and in Banffshire in primitive rocks. Being the ore from which the antimony of commerce is obtained, it occurs in all antimony mines.

3. Axotomous Antimony-Glance, or Jamesonite.

Axotomer Antimon-Glanz, *Mohs*.—Triple Sulphuré d'Antimoine, Plomb et Cuivre; Endellione, *Bournon*.—Antimoine Sulphuré, *Haüy*.

Specific Character.—Prismatic. $P + \infty = 101^\circ 20'$. Cleavage $P - \infty$, very perfect. $P + \infty$, $\bar{P}r + \infty$, imper.

Mineralogy.

fect. (Fig. 27.) Colour steel-grey. Hardness = 2.0,—2.5. Sp. gr. = 5.5,—5.8.

Description.—Colour steel-grey. Occurs massive, and in parallel or scopiform prismatic concretions. Lustre externally shining, internally glistening and metallic. Fracture uneven or conchoidal. Opaque. Sectile.

Constituent Parts.—Antimony 34.40, lead 40.75, sulphur 22.15, iron 2.30, with traces of zinc and copper. *Rose.*

Geognostic and Geographic Situations. It was first noticed in veins traversing clay-slate in Cornwall, and since in Hungary and Siberia.

4. Peritomous Antimony-Glance.

Peritomer Antimon-Glanz, *Mohs.*—Argent Sulphuré Antimonifère et Cuprifère, *Levy.*—Sulphuret of Antimony and Silver. *Phillips.*

Specific Character.—Prismatic. $\bar{P}r = 130^\circ 8'$. $P + \infty = 100^\circ 0'$. Cleavage $P + \infty$, perfect. Colour pale steel-grey. Hardness = 2.0,—2.5. Sp. gr. = 5.5,—5.6.

Description.—Colour pale steel-grey, inclining to silver-white. Occurs massive. Surface striated longitudinally. Lustre metallic.

Constituent Parts.—Conjectured to be a compound of antimony, sulphur, silver, and copper.

Geognostic and Geographic Situations.—Occurs in the Himmelsfurst mine, near Freyberg, in Saxony, also at Kapnick, in Transylvania.

Genus VIII.—MELANE-GLANCE.

Prismatic. Colour iron-black. Hardness = 2.0,—2.5. Sp. gr. = 5.9,—6.4.

1. Prismatic Melane-Glance, or Brittle Silver-Glance.

Prismatischer Melan-Glance, *Mohs.*—Sprödglaserz, *Werner.*—Argent Antimoine-Sulphuré Noire, *Häuy.*

Specific Character.—Prismatic. $P = 130^\circ 16'$; $104^\circ 18'$; $96^\circ 7'$. $\bar{P}r = 115^\circ 39'$. $(\bar{P} + \infty)^2 = 72^\circ 13'$. Cleavage $(\bar{P} + \infty)^2$, $\bar{P}r + \infty$. Imperfect. (Fig. 30, 29.)

Description.—Colour between iron-black and dark lead-grey. Occurs regularly crystallized and disseminated. Lustre externally splendid, internally shining, and metallic. Fracture conchoidal, and uneven. Streak unchanged. Opaque. Sectile.

Constituent Parts.—Silver 68.54, antimony 14.68, copper and arsenic 0.64, sulphur 16.42. *Rose.*

Geognostic and Geographic Situations.—Occurs in veins in primitive rocks in Hungary, Saxony, Bohemia, Peru, and Mexico.

Order XII.—BLENDE.

Streak green, red, brown, white, grey. Hardness = 1.0,—4.0. Sp. gr. = 3.9,—8.2. If metallic, is black. If not metallic, is adamantine. If streak green, the colour is iron-black. If streak brown or white, the sp. gr. is between 4.0 and 4.2; tessular, cleavage perfect. If streak red, the sp. gr. = 4.5, and more; hardness = 2.5, and less. If sp. gr. = 4.3 and more, the streak is red.

Genus I.—MANGANESE-BLENDE.

Glanz-Blende, *Mohs.*—Manganese-Blende, *Werner.*—Manganese Sulphuré, *Häuy.*

Tessular. Streak green. Hardness = 3.5,—4.0. Sp. gr. = 3.9,—4.05.

1. Hexahedral Manganese Blende.

Hexahedrische Glanz-Blende, *Mohs.*—Manganese Sulphuré, *Häuy.*

Specific Character.—Tessular. Cleavage hexahedral, perfect.

Description.—Colour iron-black, which, on exposure, becomes brownish-black. Streak greenish-grey. Occurs

regularly crystallized; in granular concretions, massive, and disseminated. Lustre splendid, shining, and metallic, inclining to imperfect metallic. Slightly brittle. Opaque.

Constituent Parts.—Protoxide of manganese, 62.6, sulphur 37.0. *Arfwedson.*

Geognostic and Geographic Situations.—This rare mineral occurs in Cornwall and in Transylvania, in primitive and transition rocks.

Genus II.—ZINC BLENDE, or GARNET-BLENDE.

Tessular. Streak grey, white, reddish-brown. Hardness = 3.5,—4.0. Sp. gr. = 4.0,—4.2.

1. Dodecahedral Zinc-Blende.

Dodecaedrische Granat-Blende, *Mohs.*—Blende, *Werner.*—Zinc Sulphuré, *Häuy.*

Specific Character.—Tessular. Combination semi-tessular of inclined planes. Cleavage dodecahedral, very perfect.

Description.—Colours brown, yellow, grey, green, red, and black. Occurs regularly crystallized, also in granular and fibrous distinct concretions, massive, and disseminated. Lustre ranges from specular splendid to glimmering, and is adamantine. Ranges from transparent to opaque. Brittle, and easily frangible.

The varieties in which the yellow colours predominate are named *yellow zinc-blende*; those in which the brown colour predominate, *brown zinc-blende*; and, lastly, those in which black is the characteristic colour are named *black zinc-blende*.

Constituent Parts.—Zinc 65.50, iron 1.37, sulphur 32.63. *Thomson.*

Geognostic and Geographic Situations.—Beautiful yellow varieties are met with in the old lead-mines of Tyn-drum, in Perthshire; the brown, or common blende, in every lead-mine in England and Scotland; while the black variety, which is the rarest, occurs in small quantity in Saxony, and some other mining countries on the Continent of Europe.

Genus III.—ANTIMONY-BLENDE, or PURPLE BLENDE.

Purpur-Blende, *Mohs.*

Prismatic. Streak cherry-red. Hardness = 1.0,—1.5. Sp. gr. = 4.5,—4.6.

1. Prismatic Antimony-Blende, or Purple Blende.

Prismatische Purpur-Blende, *Mohs.*—Roth Spiesglas-erz, *Werner.*—Antimoine Oxydé Sulphuré, *Häuy.*

Specific Character.—Prismatic. Combination hemiprismatic. Cleavage prismatic, very perfect.

Description.—Colour cherry-red, frequently with a tempered steel tarnish. Occurs regularly crystallized; in granular, scopiform, and stellular fibrous concretions. Lustre shining and adamantine. Opaque, or translucent on the edges.

Constituent Parts.—Antimony 67.5, oxygen 10.8, sulphur 19.7. *Klaproth.*

Geognostic and Geographic Situations.—Occurs in small quantity in primitive rocks, in Saxony, France, and Hungary.

Genus IV.—RUBY-BLENDE.

Rubin-Blende, *Mohs.*

Rhombohedral. Prismatic. Streak red. Hardness = 2.0,—2.5. Sp. gr. = 5.2,—8.2.

1. Rhombohedral Ruby-Blende, or Red Silver.

Rhomboedrische Rubin-Blende, *Mohs.*—Rothgiltigerz, *Werner.*—Argent Antimoine Sulphuré, *Häuy.*

Specific Character.—Rhombohedral. Rhombohedron = $108^\circ 18'$. Combination sometimes with different planes on opposite extremities. Cleavage rhombohedral. Streak cochineal-red. Hardness = 2.0,—2.5. Sp. gr. = 5.4—5.9.

Mineralogy.

Mineralogy.

Description.—Colour between cochineal-red and dark lead-grey, and sometimes inclining to carmine-red. Occurs regularly crystallized; massive and disseminated. Lustre ranges from splendid to glimmering, and is adamantine. Fracture uneven or conchoidal. Ranges from opaque to transparent.

Constituent Parts.—Silver 58.95, antimony 22.84, sulphur 16.61. *Bonsdorf.*

Geognostic and Geographic Situations.—In some silver mines it is an abundant ore; in this country it has been hitherto found only in Cornwall.

2. Hemiprismatic Ruby-Blende.

Hemiprismatische Rubin-Blende, *Mohs.*—Rothgiltigerz, *Werner.*

Specific Character.—Hemiprismatic. $\frac{P}{2} = 128^\circ 59'.$

$P + \infty = 86^\circ 4'.$ Cleavage $\frac{2}{3}Pr + 2$, $Pr + \infty$, imperfect.

Streak dark cherry-red. Hardness = 2.0,—2.5. Sp. gr. = 5.2,—5.4.

Description.—Colour iron-black. Streak dark cherry-red. Occurs in crystals more or less regularly formed. Lustre intermediate between metallic and adamantine. Fracture conchoidal and concealed foliated. Very sectile. Opaque, but when viewed by transmitted light, thin splinters shew a deep blood-red colour.

Constituent Parts.—Antimony 39.14, silver 36.40, sulphur 21.95, copper 1.06, iron 0.62. *Rose.*

Geognostic and Geographic Situations.—This very rare mineral occurs along with argentiferous arsenic pyrites, in one of the mines of Braunsdorf, near Freyberg in Saxony.

3. Peritomous Ruby-Blende, or Cinnabar.

Rubin-Blende, *Mohs.*—Mercure Sulphuré, *Haüy.*

Specific Character.—Rhombohedral. Rhombohedron = $71^\circ 47'.$ Cleavage $R + \infty$, very perfect. Streak scarlet-red. Hardness = 2.0,—2.5. Sp. gr. = 6.7,—8.2.

Description.—Colours cochineal and scarlet-red, and sometimes inclines to dark steel-grey. Occurs regularly crystallized; in granular and globular concretions; massive, disseminated, and dendritic. Lustre ranges from splendid to glimmering, and is adamantine, verging on semi-metallic. Fracture uneven, conchoidal, and earthy. Ranges from transparent to opaque. Sectile, and easily frangible.

The dark-coloured varieties, inclining to steel-grey, are named *hepatic cinnabar*, the others *common cinnabar*.

Constituent Parts.—Mercury 84.50, sulphur 14.75. *Klaproth.*

Geognostic and Geographic Situations.—Cinnabar is named "the ore of mercury," because the mercury of commerce is obtained from it. The principal mines of this mineral are Almaden in Spain, and Idria in Carinthia. It also occurs in the Palatinate, Carinthia, Transylvania: Japan, Mexico, and Brazil. The formations in which it is contained are gneiss, porphyry, greywacke, limestone, the coal formation.

Order XIII.—SULPHUR.

Not metallic. Colour yellow, red, brown. Prismatic. Hardness = 1.0,—2.5. Sp. gr. = 1.9,—3.6. If monotonous, the sp. gr. = 3.4, and more; if sp. gr. above 2.1, the streak is yellow or red.

Genus I.—SULPHUR.

Prismatic. Hardness = 1.5,—2.5. Sp. gr. = 1.9,—3.6.

1. Prismatic Sulphur, or Yellow Orpiment.

Prismatoidischer Schwefel, *Mohs.*—Gelbes-Rauch gelb, *Werner.*—Arsenic Sulfuré jaune auripigment, *Haüy.*

Specific Character.—Prismatic. $Pr = 83^\circ 37'.$ $P + \infty$

= $117^\circ 49'.$ Cleavage $Pr + \infty$, perfect. Streak lemon-yellow. Hardness = 1.5,—2.0. Sp. gr. = 3.4,—3.6.

Description.—Colour lemon-yellow. Occurs regularly crystallized; in granular and concentric lamellar concretions; massive, disseminated, stalactitic, reniform, botryoidal, and in crusts. Lustre splendid, between adamantine and semi-metallic. Translucent. Sectile. Flexible, but not elastic.

Constituent Parts.—Arsenic 61.86, sulphur, 28.14. *Lau-gier.*

Geognostic and Geographic Situations.—Occurs in veins in various metalliferous formations in primitive and secondary rocks in Hungary and Germany.

2. Hemiprismatic Sulphur, or Red Orpiment.

Hemiprismatischer Schwefel, *Mohs.*—Roths-Rausch gelb, *Werner.*—Arsenic Sulphuré Rouge. *Haüy.*

Specific Character.—Hemiprismatic. $\frac{P}{2} = 130^\circ 1'.$

$P + \infty = 74^\circ 30'.$ Cleavage $\frac{Pr}{2} = 66^\circ 44'.$ $P + \infty$, $Pr + \infty$, imperfect. (Fig. 36, 30, 28.) Streak orange-yellow...aurora-red. Hardness = 1.5,—2.0. Sp. gr. = 3.5,—3.6.

Description.—Colour aurora-red, inclining sometimes to orange-yellow. Occurs regularly crystallized; massive, disseminated, and in flakes. Lustre shining, and adamantine. Fracture uneven. Translucent and semi-transparent. Brittle, and easily frangible.

Constituent Parts.—Sulphur 30.43, arsenic 69.57. *Lau-gier.*

Geognostic and Geographic Situations.—Occurs in veins in primitive rocks, also in transition, secondary, and volcanic rocks. Germany, Hungary, Bohemia, Aetna, and Vesuvius, are localities.

3. Prismatic Sulphur, or Common Sulphur.

Prismatischer Schwefel, *Mohs.*—Naturlicher Schwefel, *Werner.*—Soufre, *Haüy.*

Specific Character.—Prismatic. $P = 106^\circ 38'.$ $84^\circ 58'.$ $143^\circ 17'.$ $P + \infty = 101^\circ 59'.$ Cleavage $P, P + \infty$, imperfect. (Fig. 30.) Streak white or sulphur-yellow. Hardness = 1.5,—2.5. Sp. gr. = 1.9,—2.1.

Description.—Colours yellow, brown, and grey. Occurs regularly crystallized; in granular distinct concretions; massive, disseminated, stalactitic, vesicular, and corroded. Lustre ranges from shining to glimmering, and is between adamantine and resinous. Fracture uneven, splintery, or conchoidal. Translucent and transparent. Brittle, and easily frangible.

Geognostic and Geographic Situations.—Occurs most abundantly in secondary, tertiary, and volcanic rocks; is met with also in transition and primitive rocks. Important localities are Sicily, Italy, Spain, and the island of Iceland.

CLASS III.

Specific gravity under 1.8. If liquid, the smell is bituminous. If solid, is tasteless.

Order I.—RESIN.

Hardness = 0.0,—2.5. Sp. gr. = 0.7,—1.6. If sp. gr. = 1.2, and more, the streak is white or grey.

Genus I.—MELLITE, or HONEY-STONE.

Melichron-Resin, *Mohs.*

Pyramidal. Hardness = 2.0,—2.5. Sp. gr. = 1.4,—1.6.

1. Pyramidal Mellite, or Honey-Stone.

Pyramidales Melichron-Harz, *Mohs.*—Honigstein, *Werner.*—Mellite, *Haüy.*

Mineralogy.

Mineralogy.

Specific Character.—Pyramidal. Pyramid = $118^{\circ} 4'$; $-93^{\circ} 22'$. Cleavage pyramidal, but imperfect.

Description.—Colours yellow or red. Occurs regularly crystallized and massive. Lustre shining or splendid, and vitreo-resinous. Fracture conchoidal, semi-transparent, or translucent. Brittle.

Constituent Parts.—Alumina 14.5, mellitic acid 41.4, water 44.1. *Wohler.*

Geognostic and Geographic Situations.—This rare and remarkable mineral has hitherto been found only at Artern in Thuringia, where it is associated with brown coal.

Genus II.—MINERAL-RESIN.

Erd-harz, *Mohs.*

Amorphous. Hardness = 0.0,—2.5. Sp. gr. = 0.8,—1.2.

1. Yellow Mineral Resin, or Amber.

Gelbes Erd-harz, *Mohs.*—Bernstein, *Werner.*—Succin, *Haiiy.*

Specific Character.—Solid. Colour yellow...white. Streak white or grey. Hardness = 2.0,—2.5. Sp. gr. = 1.0,—1.1.

Description.—Colours yellow and white. Occurs massive and disseminated; often incloses insects, leaves, and other parts of vegetables, also corals, &c. Lustre ranges from splendid to glistening, and is resinous. Fracture conchoidal. Transparent and translucent. Brittle, and easily frangible.

Constituent Parts.—Carbon 70.68, hydrogen 11.62, oxygen 7.77. *Ure.*

Geognostic and Geographic Situations.—This beautiful mineral occurs imbedded in alluvial and tertiary formations. The finest masses are those found in the low, flat, and alluvial countries on the shores of the Baltic. It is occasionally met with on the coasts of Scotland and England.

2. Black Mineral-Resin.

Schwarzes Erd-harz, *Mohs.*—Bitume, *Haiiy.*

Specific Character.—Solid...liquid. Colour black, brown, yellow, grey. Streak black, brown, yellow, grey. Hardness = 0.0,—2.0. Sp. gr. 0.8,—1.2.

Description.—Colours white, grey, yellow, brown, and black. Occurs massive, disseminated, globular, reniform, stalagmitic, and liquid. Lustre resinous, and ranging from splendid to glimmering. Fracture earthy, conchoidal, and slaty. Ranges from transparent to opaque.

The yellowish-white, yellowish-grey, and wine-yellow, liquid transparent varieties are named *naphtha*; the blackish brown, liquid, and translucent or opaque varieties are named *mineral ore*, or *petroleum*; the blackish-brown solid varieties, with earthy fracture, are described under the name *earthy mineral-pitch*; the pitch-black varieties, with splendid shining lustre and conchoidal fracture, are the *slaggy mineral-pitch*, or *asphaltum* of authors; and lastly, the brown, massive, curved slaty, and elastic varieties are named *elastic mineral-pitch*, *elaterite*, or *mineral caoutchouc*.

Geognostic and Geographic Situations.—The naphtha and mineral-oil flow from rocks of limestone and of the coal formations. The finest varieties of the former are found on the shores of the Caspian, the latter occurs at St Catharine's, in the vicinity of Edinburgh, and in several other places in Scotland and England. The earthy mineral-pitch is a rare mineral, and has been hitherto found principally in the Hartz; the slaggy mineral pitch is met with imbedded in the limestone, ironstone, and sandstone of the coal formation in the middle district of Scotland; and the elastic mineral-pitch has been hitherto found chiefly in the lead-mine called Odin, to the north of Castletown in Derbyshire.

Order II.—COAL.

Mineralogy.

Streak brown, black. Hardness = 1.0,—2.5. Sp. gr. = 1.2,—1.6.

Genus I.—MINERAL COAL.

Amorphous. Hardness = 1.0,—2.5. Sp. gr. = 1.2,—1.6.

1. Bituminous Mineral-Coal.

Harzige Stein-kohle, *Mohs.*—Braunkohle, and Schwartzkohle, *Werner.*—Houille. Jayet, *Haiiy.*

Specific Character.—Colours black and brown. Resinous lustre. Bituminous smell. Peat smell. Hardness = 1.0,—2.5. Sp. gr. = 1.2,—1.5.

Description.—Colours brown, black, and grey. Occurs massive, ligniform, and rarely in columnar concretions. Lustre ranges from splendid to glimmering, and is resinous. Fracture earthy, conchoidal, slaty, and uneven. Opaque. Streak shining. Sectile or brittle. Easily frangible.

Those varieties of bituminous coal, in which brown is the predominating colour, with feeble lustre, more or less of the woody texture or form, easily frangible, with peat smell, are named *brown-coal*, under which division is included the *fibrous*, *earthy*, *aluminous*, *conchoidal*, and *trapezoidal brown-coal* of authors. The varieties in which the black colour predominates, and the resinous lustre is considerable, which are harder than the brown varieties, and give out on burning a bituminous smell, are named *black-coal*, of which the following kinds are enumerated by mineralogists, viz. *slate-coal*, *cannel-coal*, *foliated-coal*, *coarse-coal*, and *pitch-coal*.

Constituent Parts.—1. *Brown-Coal.* Carbon 77.10, oxygen 19.35, hydrogen 2.54, earthy parts 1.00. *Karsten.*—2. *Best Newcastle Coal.* Carbon 84.99, hydrogen 3.23, oxygen 11.78.

Geognostic and Geographic Situations.—The brown coal occurs principally along with rocks of the tertiary class; the coal of Bovey in England may serve as an example of it in this island; the black-coal never occurs in tertiary formations, always in beds in secondary rocks, and principally in that group or series of strata and beds named the coal formation. The principal coal-mines in Scotland and England are situated in the coal formation.

2. Glance-Coal. Blind Coal. Kilkenny Coal.

Harzlose Steinkohle, *Mohs.*—Anthracite, *Haiiy.*—Glanzkohle, *Werner.*

Specific Character.—Colour black. Imperfect metallic lustre. No bituminous smell. Hardness = 2.0,—2.5. Sp. gr. = 1.3,—1.6.

Description.—Colour generally iron-black. Occurs in fibrous and columnar distinct concretions; massive, vesicular, and disseminated. Lustre ranges from splendid to glimmering, and is imperfect metallic or silky. Fracture conchoidal, uneven, and slaty. Opaque. Some varieties soil. The varieties with splendid lustre and conchoidal fracture are named *conchoidal glance-coal*; those with slaty structure *slaty glance-coal*; the columnar varieties *columnar glance-coal*; and the fibrous and soiling varieties *fibrous glance-coal* or *mineral charcoal*.

Constituent Parts.—1. *Kilkenny*, 97 per cent. of carbon. —2. *Rhode Island*, 94 per cent. of carbon.

Geognostic and Geographic Situations.—Glance-coal, like black-coal, occurs in beds in the coal formation in the secondary class of rocks. Kilmarnock, Saltcoats, and Sanguhar, may be mentioned as localities; it also occurs in veins and imbedded masses in secondary trap, as in the Calton-Hill at Edinburgh. It differs from the other kinds of coal, by its occasional appearance in rocks of the primitive class.

All the figures referred to after No. 26. are contained in Plate CCCLXIII.

II.—GEOLOGY.

OBJECTS OF GEOLOGICAL SCIENCE.

Geology.

THE reasoning employed in geology is, for the most part, analogical. Observation of the phenomena which now take place in nature, gives us the characteristic effects of modern agencies or causes; comparison of these phenomena with those produced in ancient geological periods, determines the agreement or disagreement in their respective causes; the object of sound geology is to combine the whole series of observed phenomena and inferred causes or agencies into one general history of the successive conditions of our globe, and the changes which have happened to it since the epoch when the present laws of organic and inorganic nature were appointed. We cannot assume that these laws have always been operating under the same circumstances as now, but we are justified in admitting, as a basis of reasoning, that similar natural circumstances in past and present times were consequences of similar preceding agencies, and productive of similar subsequent effects. It is evident that, in proportion to our knowledge of the characteristic effects of modern agencies, separate and combined, will be the power of referring to their proximate causes the phenomena of ancient nature; the more correct and complete this knowledge, the more exact and extensive is the basis of geological theory. The influence of a right view of existing nature is also sensible in directing the researches of observers towards the most important and characteristic circumstances of the phenomena which are to be explained.

The laws of nature are constant, but so adjusted to the material world that the effects they produce are proportioned to quantity and kind of matter, situation and direction of action, and other circumstances. A precise knowledge of the effects, and a correct view of all the agencies concerned, will lead us to the determination of the conditions under which the laws operated. In no other way than this has any one of the problems of organic and inorganic Nature, as we now behold her, been solved; no other process can possibly lead to real knowledge of the prior conditions of the globe. Geology can only pretend to the rank of science in proportion as it proceeds upon the principles of the Inductive Philosophy, and is aided by the advance of collateral inquiries. The history of a science is the description of its real progress; but if geology could have no existence before the phenomena of chemistry, zoology, and mechanics were studied in relation to laws of nature, its ancient history must be of small importance. Born in our own days,—based on modern observations,—interpreted by modern philosophy,—why should we seek rational geology in the monstrous systems of astronomy and cosmogony, which once satisfied Greece and Egypt? why attempt the vain task of tracing the various errors of those writers of later days, who, knowing nothing of chemical or vital laws, and little of mechanical science, proposed hypotheses instead of collecting facts, and referred phenomena, which they had not correctly observed, to forces which they had never truly ascertained; resigned the beautiful monuments of ancient life, the fossil remains of animals and plants, to a plastic force of Nature, and attributed the regular and orderly structure of our planet to a general destruction and ruin of an earlier sphere?

PROGRESS OF GEOLOGY.

Exactly in proportion to the progress of collateral science is the dawning of geological inquiry. The improvement of mechanical science effected by Galileo and Newton opened, after a long interval, the minds of Mitchell and Saussure to a perception of the effects of great convulsions in the crust of the globe; the progress of chemical philo-

sophy awakened, amongst the mining schools of Sweden and Saxony, these zealous efforts to develop the history of the mineral constituents of the globe which led to the Wernerian system of Geognosy; but it was reserved to modern days and more refined knowledge of natural history, to establish sound general principles of investigation concerning organic remains, and to unfold the successions of living nature, which constitute the basis of the truths established by Smith and Cuvier.

The very essence of geology, then, is such, that its conclusions can only be established in consequence of the general progress of the natural sciences; on the other hand, it makes no step without consolidating and enlarging our knowledge of existing nature; and thus it is inseparably united with the general march of the human intellect, and supported by the sympathy of all those who look with wonder and curiosity on the visible works of God.

Those who have taken a narrow view of this great and growing branch of human knowledge, who have satisfied themselves with collecting a few fossil shells, naming a few compound rocks, and constructing a few sections and maps, may possibly be startled at the mighty circle of perpetual research in which they are unconsciously engaged; yet as, in every branch of natural science, the generalizations which are the object of inquiry can only be based on accurately ascertained facts, every one who is really employed in investigating any of the phenomena of nature, must be hailed as a useful coadjutor to geology. The time is come when enough of general truth is known in geology to direct the labours of observation into right and fertile channels; and those who are best acquainted with the actual state of the science, and most sensible of its many desiderata, will be most likely to devise the best means of supplying them. This consideration should diminish the distrust which men of exact observation feel for the researches of theorists. Theory and useful observation must proceed or be retarded together; a man who is not taught how to observe, and instructed what to observe, is just as likely to mislead by his descriptions of phenomena, as a theorist who leaves the true path of inductive philosophy, substitutes hypothesis for inference, and contends for the ideal speculation instead of working out the true law of nature.

What is possible to be known.—All human knowledge is limited; but who has reached the boundary in any direction? Doubtless there are geological problems which can never be solved, many recondite laws which can never be disclosed by investigation of visible phenomena; but yet the progress of the human mind, or rather the combination and mutual irradiation of ascertained truths, continually removes farther and farther the visible barrier of knowledge, and renders possible many problems once despaired of.

The province of direct geological observation is limited to a small depth below the surface of the globe, and nothing but the progress of a higher science could give us any information as to the interior. But even those dark and unapproachable regions are not wholly hidden from the astronomer; some material properties of the central regions of our planet are already revealed by refined mathematical interpretation of the phenomena of the universe; and though we may never know *what* are the chemical qualities of the substances more than a few miles below the surface of the earth,—never be able, in ordinary language, to say *what sort* of matter composes the interior, yet many of its most important properties, as weight, density, temperature, may be at least partially ascertained, and their state of rest or motion, fluidity or solidity, made the subject of probable inference.

Direct observation may fail to give us complete information concerning the many previous conditions of the sur-

Geology. face of our planet, because it is not certain that monuments remain of all the changes which have occurred, and, if they do remain, it is not probable, or possible, that we can examine them all; a minute and continuous history of the physical revolutions of the globe is therefore not to be attempted, at least for a long time to come; but, just as from the incomplete history of the human race, principles are derived which shed a clearer light on the darkness of antiquity, determine the epochs of its changes, and discover more certainly the true relative condition of the *existing* races of men,—so the general rules of geology contribute continually to fill up the void spaces in its monumental history, to determine the amount of physical changes performed in particular geological periods, to ascertain the rate and progress of such changes, and thus to characterize the present aspect of nature by reference to many previous ascertained conditions of it.

General data.—The most important of all the data for geological theory are derived from other and very distinct branches of science. It is to astronomy and general physics that we are indebted for the establishment of some leading principles which must ever be observed in reasoning on the revolutions of the globe, and in fact form the only general basis for such reasoning. The singular prejudices which yet prevail, among good observers in geology, as to the real objects and aims of the science, apply even to the facts furnished by astronomy for the guidance of geology; and sure consequences legitimately drawn from considerations of the figure and density of our planet are often confounded, by what are called practical men, with mere speculation; and they imagine they give proof of exceeding wisdom when they reject *en masse* the independent conclusions of higher science, and the local and limited inferences from undoubted facts, as if these partial truths were mere hypotheses. Nothing is more common than to hear persons who have never qualified themselves to judge of the question, complaining of the prevailing tendency of geologists to indulge in theories; as if that most enormous and yet unattempted labour,—the construction of a general theory of the earth, was a mere morning's amusement; as if the combination of individual facts into limited generalizations, and the attempt at eliciting laws of phenomena, which in every other branch of natural science is hailed as the first proof of real progress made, should in geology alone be condemned as dangerous and delusive; as if the search after general truths, which in every other science is known to be the real object, aim, and end of the inquiry, should be in geology alone the thing of all others to be deprecated.

On the other hand, it seems no less necessary to offer a short caution to those who, seeing the great accession of local truths and partial laws of phenomena which has of late so rapidly been added to geology, are anxious to anticipate time, and think it more useful to construct a perishable hypothesis than to add to the durable foundation of theory.

Figure of the Earth.—The figure of the earth is known by direct measurement of arcs, and by experiments with the pendulum, to be a spheroid with its polar diameter about $\frac{2}{3}$ shorter than the equatorial; the former being 7899,170 miles, the latter 7925,648 miles; the difference, commonly called *the compression*, 26,478 (Herschel—*Astronomy*). This peculiar figure is a consequence of the centrifugal force of the superficial parts of the globe removed from the poles; for this diminishes the influence of gravitation, and permits the equatorial parts, where the velocity of rotation is greatest, to recede further from the axis than any other parts, till the equilibrium is obtained, and the curves over all parts of the globe correspond to a *spheroid of revolution*. The earth, then, has acquired its present figure under the joint influence of gravitation to its present centre, and rotation on its present axis; but if the mass of the globe were solid, this exact accommodation of dimensions could not take place; we must therefore add a third condition, viz. that,

in some way or other, its parts must be yielding and displaceable, fluid or loose. If the globe was formerly, or is now fluid within, wholly or in great measure, the spheroidal figure is a direct and necessary consequence, and this is the view generally adopted; but it has been imagined that even a solid globe whose superficial parts were displaceable, might, in the eternal round of natural changes, be worn down by rains and waves from a perfect sphere to a spheroid of revolution. According to this supposition the former state of the globe was very different from the present; the rotating sphere must have become very elevated land at the poles, and totally drowned in water along an equatorial band; into this equatorial sea, from the north and the south, must have been poured the waste of the high polar lands so as to form strata thickest under the equator; the poles should still be land:—but nothing of the kind appears. On the contrary, the distribution of land and water is excessively irregular, the surfaces of stratified rocks have no peculiar relation to the equator, the poles are in the midst of water, and the equatorial regions include some of the highest mountains on the globe. This hypothesis is therefore entirely gratuitous, and we must look to the interior of the earth for the displacement of substance which allowed it to assume a spheroidal figure.

Here little difficulty presents itself; it cannot be doubted that, if the interior of the globe were fluid, a spheroidal external figure must necessarily result from rotation on an axis, and the internal surfaces of equal density be also spheroidal; and both these conditions be retained whether it continued fluid or not; if it continued wholly fluid, the figure might continually adapt itself to any change of form corresponding to a variation of the ratio of central and tangential forces; if it became wholly solid, the rocks would upon such change of ratio be put in a state of strain; if internally fluid and externally solid, the crust might upon such change yield in various directions, and produce local irregularity in the distribution of land and water: finally, if the solidification of the surface were to proceed at a certain rate, compared with that of the change of ratio of the forces governing the figure, the form once acquired might be almost invariably preserved.

Of all the conditions stated above, which corresponds best to what is known concerning the earth? That its internal surfaces of equal density, are situated symmetrically with respect to the external spheroid is supposed to be true, in consequence of investigations concerning certain irregularities of the moon's motions, which depend on the figure and density of the earth. This would prove that the earth has been freely yielding within; the irregularities of the pendulum experiments appear sufficient to justify a belief that the solidification of the surface has gone to some considerable depth; the irregular distribution of the land and water appears to indicate the co-existence of a solid crust and yielding interior, accompanied by a change of form. This irregularity of land and water is the effect of great convulsions of the crust of the globe belonging to many geological periods, some of them subsequent to the existence of the present races of animals and plants. It is therefore very probable that the interior of the globe has formerly been wholly fluid; and we are not entitled hastily to reject the supposition that it is partially so at this moment.

Density of the Earth.—Taking water at a temperature of 60° as the unit of comparison, we find the specific gravity of the superficial parts of the globe, as judged of by weighing the most prevalent rocks, to be about 2.5.

By direct experiments, and comparison of the local attraction of mountains and insulated masses of matter with the general attraction of the globe, the mean density of our planet has been inferred to be about five times that of water. This result is found sufficiently in accordance with astronomical considerations to allow us to adopt it for geological reasoning.

Geology.

The interior parts of the globe must therefore be heavier than the exterior rocks.

From the influence of the earth on the moon's motions, it is inferred that the internal mass of our planet augments in density towards the centre; the surfaces of equal density being symmetrical with the external spheroidal surface. The materials of the earth have therefore collected round the centre in obedience to the laws of gravitation and rotatory movement, and the internal substances, as having fallen to the lower place when freedom of motion was allowed, would probably be heavier under the same circumstances than the superficial substances. In their present situation, their weight is augmented by the effects of the general pressure towards the centre; if the laws of compression observed among metals, stone, fluids, and gases, at the surface of the earth, obtained in the inner parts of the earth, without some counteracting cause, steel would be compressed into one-fourth, and stone into one-eighth of its bulk at the centre. Water, according to Leslie, would be as heavy as quicksilver at 362 miles depth, and air as heavy as water at thirty-four miles. (Somerville—*Connexion of Physical Science*.) Now, though we cannot presume that the law of compression would hold in these bodies to such an extent, enough is known to justify a confident belief that the mean density of our planet would be very much greater than it is, were not the tendency to enormous condensation in the central masses counteracted by some powerful agent of expansion, such as heat, or neutralized by some peculiar and unknown constitution of the substances themselves.

TEMPERATURE OF THE GLOBE.

It becomes, therefore, necessary to inquire into the subject of the earth's temperature. The superficial heat of the earth's surface is subject to several known, and probably to other unknown, influences; of the known causes of variation, the following are the most worthy of the notice of geologists:—

- 1st, The influence of the sun.
- 2d, The influence of the distribution of land and water, and the nature of the surface.
- 3d, Elevation above the mean level of the sea.
- 4th, The temperature of the circumambient space.
- 5th, The temperature of the interior of the globe.

1. The solar rays are the principal source of heat on the surface of the globe; the temperatures vary in relation to the amount of those rays; the mean temperatures consequently decrease continually from the equator toward the poles, nearly in the simple proportion of the cosines of latitude. (Mayer's formula of the square of the cosine appears very inaccurate both at the equator and toward the poles.) At every point of the earth's surface the temperature changes with the period of the year, nearly in proportion to the variation of altitude and duration of solar irradiation: it changes also with day and night. No proposition is more certain than the fundamental dependence of the temperature of the surface of the globe on the solar influence.

It is, therefore, very important for geologists to inquire whether this be variable or constant; whether the amount of solar heat communicated to the earth is and has always been the same in every annual period, or what latitude the laws of the planetary movements permit in this respect.

Sir John Herschel has examined this question in a satisfactory manner, in a paper read to the Geological Society of London. The total amount of solar radiation which determines the general climate of the earth, the year being of invariable length, is inversely proportional to the minor axis of the ellipse described by the earth about the sun, regarded as slowly variable; the major axis remaining constant, and the orbit being actually in a state of approach to a circle, and consequently the minor axis being on the in-

crease, it follows that the mean annual amount of solar radiation received by the whole earth must be actually on the decrease. The limits of the variation in the eccentricity of the earth's orbit are not known; it is therefore impossible to say accurately what may have been, in former periods of time, the amount of solar radiation; it is, however, certain, that, if the ellipticity has ever been so great as that of the orbit of Mercury or Pallas, the temperature of the earth must have been sensibly higher than it is at present. But the difference of a few degrees of temperature thus occasioned, is of too small an order to be employed in explaining the growth of tropical plants and corals in the polar and temperate zones, and other great phenomena of geology.

2. Nature of the Surface.—The heating effect of the sun's rays varies with the nature of the surface on which they fall: the colour, texture, capacity for heat, and other circumstances affecting the absorbent and reflective powers of the substances, influence, accordingly, the amount of heat absorbed and retained. The reflective surfaces of snow which cover so large a portion of the polar land, while they refuse admission to the solar heat, and contribute to warm the upper air, prevent also the dissipation of terrestrial warmth. Sandy and rocky tracts reverberate heat into the air; grassy plains and cultivated fields freely absorb heat by day, and freely radiate it by night.

Though these circumstances are little sensible in registers of annual, monthly, or diurnal temperature, they affect very seriously the growth of plants and animals, and constitute a very important character of local climate which ought to be more attended to. The large forests of equatorial regions maintain, in their ample shade, a permanent coolness, favourable to vegetation; in the temperate climates of Europe, their destruction has perhaps mitigated the periodical severity of cold. But the most important of this class of phenomena is derived from the unequal distribution of land and water upon the globe. The climate of the ocean is very different from that of the land, less extreme in its variations with season, and limited within narrow ranges over the whole watery surface. This is, in a great degree, owing to the movement of the particles of water upwards and downwards, according to the variation of temperature at the surface, and the movement of the tidal and other great oceanic currents. Thus the fluctuations of heat are not merely confined to the surface, but diffused through great depths and breadths of water, and the climates of remotest regions mixed and mutually mitigated by the beneficent movements of the sea.

On the land a similar, but less regular and continuous, influence is performed by the winds, which, by appointed laws, change and fluctuate in their paths, and cause *alteration* rather than *gradation* of climate, a variable succession of different and often extreme temperatures; so that the range of variation of heat is greater at any one point on the land than in the sea, and the difference of temperature in different latitudes is greater.

The warmest band of the ocean is that running up the Atlantic; the coldest points of the globe are in the northern part of the land of Asia and America. If, instead of so much land round a polar basin, we had broad equatorial continents and small polar isles, the temperature of the globe would have been more uniform than at present; the excessive cold of the polar circles would be reduced; some slight general augmentation of heat in the polar sea might be experienced, but not so great an addition of heat as to account for the phenomena of the growth of coral in the sea, and tree ferns on the islands.

The distribution of land and water is a variable element of importance in the question of the former temperature of the surface of the globe, but its variations must not be imagined equal to cause a change of more than a few degrees.

3. Elevation above the mean level of the sea, is another

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Geology. important circumstance affecting local climate, and the general amount of heat on the earth and in the air about it. The atmosphere surrounding the earth is not heated by the sun's rays passing through it; it freely transmits them. Clouds, and particles of all kinds in it, must arrest some heat as it radiates from the sun or from the earth, but the main supply is derived from the earth by conduction. Near the earth, the temperature of the air seldom differs from that of the surface, whether that be land or sea; and in all the higher regions, amidst the complications of aerial currents which rather alternate than mingle, we find the temperatures decrease as the density of the air diminishes, so that, at moderate heights, a diminution of 1° Fahrenheit corresponds to about 323 feet elevation. (Forbes.)

This settled law of atmospheric heat reacts on the elevated land, and causes a reduction of the mean temperature of the higher stations, exactly of the same nature, and as regularly calculable, as that depending on latitude.

4. Temperature of the Planetary System.—The temperature of the space surrounding the earth cannot be hotter than the coldest point on the surface of the globe: for, since the globe is continually receiving heat from the sun, and radiating it into space, the cooling process can only proceed so far as to reduce the surface temperature to an equilibrium with that of surrounding space.

The lowest temperature on the globe (Melville Island) being taken at 50° cent. below zero, we may be sure that the ethereal spaces have not a higher temperature. In fact, Fourier and Swanberg agree in adopting this as the real temperature of the planetary spaces. The opinion, daily gaining strength, of the universal diffusion of an elastic ether, renders probable the conclusion that the immense regions in which the planets move have a definite temperature; if the ether vary in density about different centres or systems, which is at least not improbable, the statical temperatures may vary also with situation; but, as far as we have yet learned of the solar system, there is no reason to imagine the temperature is sensibly variable with time; not even if the planets are continually losing heat.

5. Temperature of the Interior of the Globe.—Hitherto we have considered the globe as merely a recipient of heat from the sun, measured in quantity, and distributed in a particular manner. This heat is again partly dissipated into the atmosphere and ethereal spaces, so that there is no superficial accumulation of heat derived from the sun: the climates on the earth appear to be constant, except by the interference of some of the variable circumstances previously adverted to.

But we must not bind our views to the surface; the state of the interior of our planet, in relation to the intensity, constancy, and circulation of the heat there, is of the greatest possible importance.

There can scarcely be found a more striking example of the beneficial influence of geology on collateral science, than the impulse it has created toward the cultivation of the curious and delicate inquiry into the theory of internal terrestrial temperature, both among mathematicians and experimentalists. What a contrast is offered by the wild speculations of Burnet and others, concerning the constitution of the interior of the globe, and the profound conclusions of Fourier, which every succeeding experiment appears to render more certain.

But for a geological necessity, so to speak, the beautiful mathematical researches of Fourier and the experiments of Humboldt, Cordier, and others, would never have been made; and even philosophers might have been content, with the uninstructed vulgar, to have no thoughts on the matter of the earth's proper heat. There is a singular prejudice on this subject, which is worth notice, as an example of the difficulties often attending the promulgation of novel truths. Some persons are startled at the very idea of the interior of the earth being hot; as if it were some

Geology. monstrous and insufferable doctrine; as if it were something utterly unreasonable that the centre of a planet should be asserted to have a temperature very different from that of its surface. Much of the declamation against central heat, as it is incorrectly termed, has no better foundation. But how is it to be known whether the exterior of the earth may be very hot or very cold, or synthermal with the surface, except by mathematical and experimental investigation, especially directed to the question? The problem certainly is difficult, but not impossible, and it is fraught with the highest interest.

It has been proved by Fourier's mathematical investigations on the theory of heat, that the temperature of the surface of our planet being, as we know it to be, wholly dependent on the solar radiation, the interior of the mass may have any temperature whatever, any extreme of heat or cold, without producing any sensible effect on the surface.

The reason of this is very simple; the conduction of heat, by the substances near the surface of the earth, is so exceedingly slow, that ages might pass before there could be any sensible warmth communicated from even intensely hot masses placed at a moderate depth.

It appears from the mathematical theory, and it is fully established by experiment, that the fluctuations of the solar heat are experienced only to a certain depth, below which the temperature of any one point is invariable; this depth is not every where the same, but, as far as yet appears, nowhere exceeds 100 feet. The temperature at this depth is constant, and generally corresponds, at least nearly, to the mean annual temperature of the surface. The temperatures below this depth can only be known by experiment. Before stating the results of these, it may be useful to advert to the simple reasoning which must be employed in drawing conclusions from them. If it be found that the temperatures below the zone of fluctuating heat continually diminish, it is evident that the interior parts of the earth are colder than the surface, and that there is no reason to imagine the earth to have any other source of heat than solar radiation; but if the contrary be found true, the earth has a proper temperature, derived from internal sources. If the augmentation be merely a *local* phenomenon, *local* chemical action may perhaps explain it, but if it be a *general* fact, we must appeal to a corresponding general cause.

Experiments on the temperature of the interior of the globe require great attention, and must be interpreted with caution. In mines, collieries, &c., the influence of lights, respiration, &c., is considerable; in these, and almost all situations, chemical processes go on which must be considered; there are local sources of heat to be allowed for, as mineral waters, the augmented density of air, &c. Into the examination of these points it is not necessary to enter further. The reader must suppose that they have been attended to by M. Cordier, M. Arago, and others, both in selecting experiments and drawing inferences. The following examples include single and continued observations in different situations and under varied circumstances.

1. Single experiment in the deepest colliery in Great Britain at Monkwearmouth, near Sunderland, soon after the sinking of the shaft (Phil. Mag. 1834). Depth of the pit to the place of observation, 528 yards; depth below the level of the sea, 500 yards; mean annual temperature, 47.6° . Observed temperature of air at surface on the day of experiment (15th November 1834), 49° —of air at the bottom of the pit, 62° —near the forehead (or end of the drift), 64° —close to the coal, 68° . Temperature of water collected in the pit bottom, 67° —of salt water issuing from a bore hole made on the same morning, 70.1° —of similar water as it first gushed out, 71.4° —of gas bubbles issuing through the water, $72^{\circ}.6$. Temperature of the front of the coal, 68° —of the interior, $71^{\circ}.4$. A thermometer left in a bore-hole for a week, indicated $71^{\circ}.2$.

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2. Continued Experiments on Subterranean Springs.

Countries	Authors.	Mines.	Depth in Feet.	Temperature obs.	Mean Ann. Temp. of Surface.	Depth for 1° F.
Saxony	Daubuisson, 1802.	Lead and silver mine of Junghohe Birk	256	48.9	46.9	102.4
		Do. Beschertglück	712	54.5	46.4	87.
		Do. Do.	840	56.8		80.7
		Do. Himmelfahrt	735	57.9		63.9
	Gairdner, 1820.	Do. Kurprinz,	634	80.1		18.8
Brittany.	Daubuisson, Sept. 1802.	Do. Poullauen,	128	53.4	52.7	182.0
		Do. Do.	246	53.4		351.0
		Do. Do.	459	58.3		82.0
		Do. Huelgoet,	197	54.	51.8	89.5
		Do. Do.	262	59.		36.4
		Do. Do.	394	59.		54.7
		Do. Do.	755	67.5		48.4
Cornwall	Fox, 1821.	Dolcoath mine	1440	82.	50.	45.0
Mexico	Humboldt.	Guanaxato silver mine	1713	98.2	68.8	45.8

In a well at La Rochelle, depth 369½ feet, temperature observed, 18.12 C.; mean annual temperature of surface, 11.87 C.; depth for 1° F. 33 feet.

3. Continued Experiments in Rock.

Countries.	Authors.	Mines.	Depth in Feet.	Temperature obs.	Mean Ann. Temp. of Surface.	Depth for 1° F.	
First Series. In rock near the surface.							
Saxony	Von Trebra, 1805-6-7.	Mine of Beschertglück	591	52.2	46.4	101.	
		Do.	853	59.		67.	
		Do.	236	47.7		174.7	
		Do.	552	55.		63.7	
		Do.	880	59.		69.8	
		Do.	1246	65.7		64.4	
Second Series. In loose matter near the face of rock.							
Cornwall	Fox, 1821. Cordier, 1821.	United copper mines {	1142	87.4	50.	30.5	
			1201	88.		31.1	
		Carmeaux. Coal-pit of Ravin }	597	62.8	52.	55.3	
		Coal-pit of Castellan	630	67.1	52.	40.8	
		Littry. Coal-pit of St Charles }	325	61.		36.1	
		Decise. Coal-pit of St Jacobi }	351	64.		29.2	
		Do.	561	71.7		28.5	
Third Series. Three feet three inches in the rock.							
Cornwall	Fox, 1820, Register kept for 18 months.	} Dolcoath .	1381	75.6	50.	54.	Variation.
Saxony	Reich. Oct. 1829 to Oct. 1830.	Lead and silver mine of Kurprinz }	18	51.8 to 46.4			15.8
		Do.	413	59.6		31.3	3.3
		Do.	686	62.5		42.6	0.2
		Do.	1063	67.7		49.9	1.0

4. Artesian Wells (by M. Arago).

	Cent.	Metres deep.	Diff. Temp.	Metres to 1° C.
Paris.				
Mean temperature of the surface, Fontaine de la Garde St Ouen	10.6 12.9	66	23.	29.0
Dept. du Gard et des Pas de Calais.				
Mean temperature of the surface, Fontaine Artesienne de Marquette,	10.3 12.5	56	22.2	25.5
Fontaine Artesienne d'Aire,	13.3	63	3.	21.
Fontaine Artesienne de St Venant,	14.0	100	37.	27.
Sheerness, at the mouth of the Medway.				
Mean temperature of the surface, of the deep well,	10.5 15.5	110	5.	22.
Tours.				
Mean temperature of surface, of Artesian Well,	11.5 17.5	140	6.	23.3

Mean result of the six observations, 24.6 metres to 1° C.
 --- --- --- --- 13.66 metres to 1° F.
 --- --- --- --- 45 feet to 1° F.¹

The results from artesian wells, the water being pure, are probably as much to be depended on as those from mines: it is remarkable that the two classes of results coincide, for Monsieur Cordier's previous conclusion from the latter phenomena is, that the temperature augments one degree of Fahrenheit in forty-five feet English. The ratio is, however, certainly not uniform at different places, as might be anticipated from the unequal conducting power of the rocks.

It appears, then, fully ascertained, that, in situations far removed from volcanic action, in different kinds of rocks with very different chemical relations, water, air, and rocks continually grow warmer as we descend in the earth. *Without a single exception*, the interior of the globe is warmer than the surface, and the heat augments constantly with the depth. Combining this result with the mathematical inferences of Fourier, and the generalizations concerning the state of the central parts of the globe, we shall find that it is not without reason the distinguished mathematician above named has favoured the hypothesis that the earth is a cooled globe, very hot within, and still cooling slowly; so slowly, indeed, that the effects of the contraction due to this refrigeration have not been perceived by astronomers in the alteration of the length of the day, which must inevitably have occurred if the diameter of the globe had sensibly diminished. For all short periods of time, that is, for a thousand or two thousand years, the globe may now be supposed to be in a statical condition, both as to interior and superficial heat, magnitude, and figure.

The hypothesis of a cooling globe, thus brought fairly under our notice, can only be changed into theory by its accordance with geological phenomena of very ancient date, which can in no other way be so well explained.

DEPTH OF THE OCEAN.

A knowledge of the probable depth of the ocean is of importance in limiting the range of some speculations in geology. In questions concerning the relative areas of land and water, and the change of level of land and sea, it is desirable to have some notion of the quantity of water on the globe. Its area we know, but its mean depth is uncertain. Laplace and the astronomers appear to be satisfied with believing that the depths of the sea balance the elevations of the land; so that the extreme depths may not be very great, and the mean depth only a small number of miles. If we were to suppose the depths of the sea proportioned to the heights of the land, in the ratio of the

Geology. respective areas, and similar inequalities of level to prevail, the greatest depths might be taken at about fifteen miles, and the mean depth would not exceed from one to five miles, according to the supposed form of the oceanic bed.

From the investigations of Mr Whewell on the velocity of the tide-wave (Phil. Trans.), some exact knowledge on this subject is already gathering for geology. According to the supposition of Lagrange, this velocity is a function of the depth of the channel, without regard to other conditions; the velocity is in fact that which a heavy body would acquire by falling through half the depth. According to this view, the depth of the sea on the east coast of England is 120 feet, on that of Scotland 360 feet, of the Atlantic coast of Ireland 2600 feet, of the Atlantic (in its middle part) 50,000 feet, or above nine miles. These depths, judging from the soundings on the east coast of England, are good approximations; and inspection of Mr Whewell's maps of the cotidal lines seems to forbid our imagining the sea to be any where for great breadths very much deeper than the Atlantic.

On this subject Mrs Somerville observes,—“The sea has little influence on the variation of the length of the arcs of the pendulum or on gravitation, neither does it much affect the lunar inequalities. The mean depth of the ocean is very small. There may be profound cavities in the bottom of the sea, but its mean depth probably does not much exceed the mean height of the continents and islands above its level.”—(*Connexion of Phys. Science.*)

EXTENT OF THE ATMOSPHERE.

The quantity of gaseous matter floating above the earth is known by direct weighing with the barometer; analysis resolves this airy ocean into its constituent elements, and shews us the proportions of oxygen and nitrogen, which, with carbonic acid, aqueous vapour, and other variable admixtures, make up the whole mass. Is the quantity of the atmosphere constant? its composition invariable? or what are the sources and limits of variation? In the present state of meteorology these questions admit of no satisfactory answer. It is true that, within the short period of barometric measurement, no phenomena have given reason to suppose any alteration of atmospheric pressure, and that, in every case of well conducted analysis, the atmosphere has every where and always been found similarly constituted. But when we know by how many operations the air is decomposed, fixed, and released in chemical and vital combinations, how much gaseous matter is daily poured from the earth into the air, it is clearly beyond our power to affirm that the quantity and quality of the air may not be now undergoing a slow and determinate change. If study of the planetary bodies of our system appears to shew that atmospheres are not necessary accompaniments of such bodies, how can we feel confident that our own atmosphere must ever retain one peculiar quality and quantity? It is evidently possible that the sources of variation which are daily in action may not exactly reciprocate their influence, or if they do now (which no one can affirm), who shall prove to us that they have always done so? or rather, who that considers the composition of the most abundant rocks in the crust of the globe, and remarks the immense quantity of oxygen contained in them all, even to the half of their weight, can avoid imagining the liberation of that gas, and a corresponding enlargement and chemical change of the atmosphere? We cannot, however, philosophically assume that the atmosphere is changeable in quantity or quality, except in virtue of well founded inferences from phenomena pointing specially to such a supposition. A case supposed to be of this description will hereafter come under discussion.

If the dimensions of the earth or the mean temperature of its surface have been changed, the quantity and quality

of the atmosphere might remain the same, and yet its vital effects would be greatly altered.

GEOLOGICAL DATA.

Materials of the Globe.—The solid substances composing the external parts of the globe, with which alone we can become acquainted by specific observation, may be considered in several points of view, according to the object of the reasoning; but for the fundamental researches of geology, they may be all subjected to the following process or formula.

Rocks, or very considerable component masses of the globe, are composed of particular *mineral substances*, which are resolved by chemical analysis into their *proximate constituent parts*, these being further resolvable, in many instances, into *elementary or undecomposable molecules*.

Some rocks are simple, that is, composed of one kind of mineral substance, as limestone; others compound, or formed of two or more kinds of minerals, as granite; some rocks, apparently simple, as certain kinds of slate, sandstone, &c. are really composed of several minerals, minutely and equally mixed. In this respect the nomenclature of geology (and mineralogy in a less degree) is not always accurate. As examples of the processes whereby we record these different characters, we may place in the same table granite and limestone.

Names of the Rock.	Names of the Mineral Ingredients.	Their Proximate Constituent Parts.	The Elementary Constituents.
Granite.	Quartz.	Silica.	Silicium + oxygen.
		Silica.	Silicium + oxygen.
		Alumina.	Aluminum + oxygen.
		Potash.	Potassium + oxygen.
		Lime.	Calcium + oxygen.
	Felspar.	Oxide of Iron.	Iron + oxygen.
		Silica.	Silicium + oxygen.
		Alumina.	Aluminum + oxygen.
		Magnesia.	Magnesium + oxygen.
		Oxide of Iron.	Iron + oxygen.
Limestone.	Limestone.	Potash.	Potassium + oxygen.
		Lime.	Calcium + oxygen.
		Carbonic Acid.	Carbon + oxygen.

It is found that nearly all the solid, liquid, and gaseous substances which occur in or upon the globe in a natural state are compound; particular metals occur pure in nature, other substances, especially gaseous matter, are rendered so for a short time by vital and chemical operations; but it is a fact that about half the ponderable matter of those parts of the globe which we are acquainted with by exact observation, is composed of oxygen.

In the present temperature and pressure of the atmosphere, oxygen can only exist separately as an expanded gas, about $\frac{1}{8000}$ th part of the weight of water; but in the solids and liquids of the crust of the globe it is condensed to an astonishing degree. In water, it is joined with the light gas hydrogen, condensed 2000 times, and in the same or a greater proportion in the oxides of metals.

The consideration of the laws regulating the combination of the elementary and proximate constituents belongs to CHEMISTRY; the study of the inorganic compounds thus formed constitutes MINERALOGY; the history of the great masses of mineral substances which enter into the crust of the globe constitutes the principal or fundamental part of GEOLOGY, which, however, cannot be completely investigated without including many general considerations arising from the former branches of knowledge.

There are fifty-four substances known to chemists which have never been proved to be compound, and are, therefore, provisionally ranked as elementary sorts of matter. Of

Geology. these, five, when they occur in a separate state (in the ordinary temperature and pressure), are in the state of gas, viz. hydrogen, oxygen, nitrogen or azote, chlorine, fluorine. Five are volatile non-metallic bodies, viz. bromine (fluid), iodine, sulphur, phosphorus, selenium. Two are fixed (or incapable of being volatilized) non-metallic bodies, viz. carbon, boron. The remaining substances are metallic or metalloid. Seven of them are earthy metals or metalloids, which, by combination with oxygen, yield the earths, viz. silicium, aluminum, magnesium, yttrium, glucinum, zirconium, thorium. Six are alkaline metals, yielding alkalies with oxygen, viz. potassium, sodium, lithium, calcium, barium, strontium. Fifteen are metals which retain oxygen at high temperatures, viz. lead, tellurium, copper, bismuth, titanium, cobalt, cerium, uranium, antimony, columbium, tungsten, chromium, vanadium, molybdenum, arsenic. Nine are metals which part with oxygen at high temperatures, viz. mercury, silver, gold, platinum, palladium, rhodium, iridium, osmium, nickel. Five absorb and retain oxygen at high temperatures, and decompose water at a red heat, viz. tin, iron, zinc, cadmium, manganese.

Most abundant substances.—The most abundant (and on that account the most important to the geologist) of the elementary substances enumerated are oxygen, hydrogen, chlorine, sulphur, phosphorus, carbon, silicium, potassium, sodium, calcium, magnesium, aluminum, iron, manganese.

Most abundant minerals.—The minerals formed by the combination of the several ingredients among one another are doubtless very numerous; already several hundred species have been recognised, but of these many are exceedingly rare, and others occur only in particular situations, so that the principal rocks of the globe are formed of only a small number of mineral substances. The geologist is not absolutely required, except for particular trains of reasoning, to be an accomplished mineralogist; but it seems unwise to countenance the neglect of mineralogy, which appears to have become not unusual among those who have been foremost to cultivate the zoological principles of geology. We must not grant to the lovers of organic remains that a person may be too good a mineralogist to be a good geologist.¹

It will be scarcely possible to make any useful progress in examining or describing rocks, unless the student is able to recognise and distinguish the following minerals.²

Quartz,	Green earth,
Felspar,	Talc,
Mica,	Steatite,
Hornblende,	Garnet,
Actynolite,	Carbonate of lime,
Augite,	Carbonate of magnesia,
Hypersthene,	Sulphate of lime,
Diallage,	Chloride of sodium,
Schorl,	Bitumen,
Chialtolite,	Iron, oxide of,
Chlorite,	... sulphuret of,

Supposing that at least some knowledge has been acquired of these substances, the student of geology may quickly obtain the power of recognising and discriminating the following simple and compound earthy masses (commonly called rocks), which are selected as being of frequent occurrence in the crust of the globe.

Limestone, including crystallized, compact, chalky, volatile, earthy, &c. calcareous rocks,	Shale,
Sandstone,	Slate,
Clay,	Chert,
	Flint,
	Coal,
	Ironstone,

Granite,
Sienite,
Melaphyre,
Greenstone,

Wacke,
Basalt,
Hypersthene rock,
Diallage rock,
Serpentine,

Felspar rock,
Claystone,
Hornstone,
Pitchstone,

Gneiss,
Mica schist,
Chlorite schist,
Quartz-rock,
Hornblende schist.

} all locally porphyritic and amygdaloidal.

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Construction of the Crust of the Globe.—It cannot with truth be said that the arrangement of materials in the crust of the globe has ever been entirely unknown, because the operations of mining, however ignorantly begun and conducted, must infallibly have led to correct, though very limited, information concerning it. No considerable mining region in the civilized world has ever been visited by geologists where the structure of the metalliferous mountains has not long been partially known. What geologist has been able to add to the knowledge of this kind possessed by the old miners of Aldstone Moor? In what coal district have the workmen been found wholly ignorant of the succession of the sandstones, shales, and coal in which their operations are conducted?

The great step made by modern geology has been, to unite this scattered information into general truths; and it appears unnecessary to go farther back than to Werner for the proposal of correct views on this subject in Germany; to Saussure in Switzerland; and Smith in England.

In the latter country, it is true that Mitchell had made some correct researches, more general than could be expected at the period, and Whitehurst shewed himself possessed of enlarged views; but it is undoubtedly to Werner and Smith that the modern system of geology, founded on correct observations of the arrangement of rocks, owes its rapid advances.

The essential principles admitted by both these eminent men are very simple; they affirm that the materials in the crust of the globe are generally stratified, and that the strata succeed one another in a particular order or series. This is nothing more than asserting generally what is in very many instances found to be true locally by the experience of miners, colliers, well-sinkers, quarrymen, and others.

For the purpose of shewing more clearly the state of knowledge on this fundamental point, we shall suppose five independent observers engaged in inquiring into it, with all the aids of local knowledge furnished by mines, collieries, and other excavations made by men, and abundance of cliffs, ravines, and mountain slopes where nature displays her works. One of them may be situated in the vicinity of London, another in Oxfordshire, another in Yorkshire, a fourth in the region of the English lakes; a fifth in the Highlands of Scotland.

Neglecting the variable and irregular covering of soil, gravel, sediment from rivers, &c.; the deep wells, and other excavations in the neighbourhood of London, will prove to the first observer that similar materials lie below the surface for a considerable breadth of country, that they are stratified or collected into masses which have a very great horizontal extension, and small comparative thickness; that, taken on a great scale, the series of beds is reducible to three leading terms, thus:—

Great clay of London and the vicinity at the top.
Series of sands and clays of different kinds in the middle.
Chalk at the bottom.

¹ See on this subject Whewell's *Report on Mineralogy to the British Association*, 1832.

² See Jameson's *Mineralogy*, MacCulloch on *Rocks*, Phillips' *Guide to Geology*, &c.

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The Oxfordshire observer in the same manner finds that the rocks of the county are all stratified, or widely extended in nearly horizontal masses, and laid one upon another, so that the following is a general type of the series, including some parts of Warwickshire :

Chalk at the top.
Clay and sands.
Oolitic limestones, clays, and sands.
Blue clays, blue limestones, &c.
Red clays, and red sandstones at the bottom.

The Yorkshire observer finds the rocks stratified, of definite thickness, and lying in the following order :

Chalk at the top.
Clays.
Oolitic limestones, &c.
Blue clays and limestones.
Red clays and red sandstones.
Magnesian limestone.
Coal with sandstones and shales.
Limestone, &c.
Argillaceous slate rocks at the bottom.

In the district of the lakes, the stratification of some rocks is certain, of others obscure, and some are not stratified. The series of the stratified rocks, ascertained with great difficulty, is thus recorded :

Red clay and sandstone.	Slate rocks.
Coal, &c.	Red argillaceous rocks.
Limestone, &c.	Slate-rocks.
Slate-rocks.	Gneiss and mica schist.
Limestone.	

Below all these is granite, which does not appear to be stratified.

Finally, the observer in the Highlands finds it often difficult to say whether the rocks are wholly, partially, or not at all stratified. After infinite labour, he decides that some are, and others not. The series of predominant stratified rocks is,

Red conglomerate and sandstone,
Argillaceous slate.
Chlorite schist, &c.
Mica schist, &c.
Gneiss, &c.

And under these is granite, which nowhere appears to be really stratified.

Thus we have two classes of rocks, stratified and unstratified, which will require distinct examination.

Stratified Rocks.—In each of the localities specified, the series of strata is found to be constant, not that every particular stratum is everywhere observed; but the *order in which they succeed one another when present together, is never reversed.* This is consistent with all experience.

It is found by actual observation, that the chalk, which is the lowest mass of strata noticed in the vicinity of London, is continuous with, and forms a part of, that chalk which is at the top of the Oxfordshire series. It is also found that this same chalk is actually traceable, with little interruption, in a very clear and satisfactory manner, from Oxfordshire into Yorkshire, where also it forms the top of the section; that the oolitic rocks, the blue clays and limestones, the red clays and red sandstones are in the same way continued from Oxfordshire to Yorkshire. The same stratified rocks then occur in very distant situations in the same order of succession, having certain rocks above them. If, now, we compare the Yorkshire and Cumbrian, and afterwards the Cumbrian and Scottish series of rocks, we shall find several

common terms in similar parts of the series, and thus be able to unite all the five sets of observations into one general view.

The continuity of the strata near the surface of the earth, and the constancy of their order of succession being thus shewn to be capable of exact proof, we may suppose not five but many thousand points and lines in the surface of the British islands to have undergone a scrupulous examination, with a view first to test the laws, and afterwards to exemplify their application. In consequence, they are unequivocally established, and the following is a general arrangement of the groups of strata, discovered in the British islands, proceeding from the surface downwards. It is supposed that all the alluvial and detrital covering of the surface is removed.

TABLE OF BRITISH STRATIFIED ROCKS.

Names of Formations or Groups of Strata.	Thickness in yards.	Subdivisions adopted.	Remarks.
TERTIARY STRATA.			
Crag, .	16	{ Upper or red crag. Lower or coralline crag, . . . }	{ Shells, pebbles, sand, &c. Shells and corals in sand or limestone.
Fresh - water group, . }	33	{ Upper fresh-water beds, . . . Estuary marls, . Lower fresh-water beds, . . . }	{ Fresh-water shells in marl or limestone. Estuary shells in marl. Fresh-water shells in marl or limestone.
London clay, {	200 to 600	{ London clay, . Plastic clay and sands, . . . }	{ Shelly clay with Septaria. Coloured sands and clays, with or without shells.
SECONDARY STRATA.			
<i>Cretaceous System.</i>			
Chalk, .	200	{ Upper chalk, . Lower chalk, . Chalk marl, . }	{ Soft, with flints. Harder, with or without flints. Soft argillaceous beds.
Green-sand, {	160	{ Upper green sand, Gault, . . . Lower green sand, }	{ Fossiliferous, often chalky. Blue marl or clay, fossiliferous. Often ferruginous, fossiliferous.
<i>Oolitic System.</i>			
Wealden, .	300	{ Weald clay, . Hastings sands, Purbeck beds, . }	{ Clay, with fresh - water shells. Sandstone, with plants, &c. Clay and limestone, with fresh-water shells.
Upper or Portland oolite, }	100 to 200	{ Portland oolite, Sand, . . . Kimmeridge clay, }	{ Limestone, often cherty and fossiliferous. Sand. Blue clay, with shells.
Middle, or Oxford oolite, . }	150	{ Upper calcareous grit, . . . Coralline oolite, Lower calcareous grit, . . . Oxford clay, . Kelloways rock, }	{ Sandstone, often shelly. Shelly oolite and coral beds. Shelly sandstone. Clay, with shells and septaria. Sandstone, with shells.

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TABLE OF BRITISH STRATIFIED ROCKS—continued.

Names of Formations or Groups of Strata.	Thickness in yards.	Subdivisions adopted.	Remarks.	Names of Formations or Groups of Strata.	Thickness in yards.	Subdivisions adopted.	Remarks.
Oolitic System—continued.				PRIMARY STRATA.			
				Silurian System, as it occurs on the border of Wales.			
Lower, or Bath Oolite, ¹	150	Clay, . . .	Generally with few shells.	Ludlow Rocks,	660	Sandstones, . . .	Argillaceous sandstone, shelly.
		Cornbrash, . . .	Coarse shelly limestone.			Limestones, . . .	Shelly and coralloidal.
		Sand, . . .	With concretionary sandstone.	Wenlock Rocks, . . .	600	Limestone, . . .	Abounding in zoophytes, trilobites, &c.
		Forest marble, . . .	Shelly limestone.			Shale, . . .	
		Clay, . . .	Thin blue clay.	Caradoc Rocks, . . .	830	Shelly limestone, . . .	
		Bath oolite, . . .	Shelly compact and sandy oolite.			Shelly sandstone, &c.	
		Fuller's earth, . . .	Calcareous and argillaceous beds.	Llandeilo Rocks, . . .	400	Calcareous laminated beds, . . .	With trilobites, &c.
		Inferior oolite, . . .	Shelly and oolitic.				
Lias, . . .		Sand, . . .	Shelly calcareous sand.				
		Upper lias shale, . . .	Blue clay or aluminous shale, shelly.				
		Marl-stone, . . .	Sandy limestone, &c., shelly.				
		Middle lias shale, . . .	Blue clay or shale, shelly.				
		Lias Limestones, . . .	Blue and white compact limestone, shelly.				
		Lower lias shale, . . .	Coloured clays and marls.				
		Red Sandstone System.				Grauwacke System, as it occurs in Wales.	
New Red Sandstone,	300	Variegated marls, . . .	Contain gypsum and rock-salt, shells rarely found.	Plynlimmon Rocks,	un-known		Hard, slaty, fine or coarse grained rock, with few or no organic remains.
		Variegated sandstones, . . .	Red, white, &c. sandstones, no shells.	Bala limestone,	unkn.		Dark, laminated, slaty limestone, with fossils.
		Conglomerate, . . .	Pebbly sandstone.	Snowdon rocks,	unkn.		Hard slaty rocks, with (locally) few organic remains.
Magnesian Limestone, ²	100	Knottingley limestone, . . .	Thin-bedded close-grained limestone, with few shells.	Clayslate System, as it occurs in Cumberland and Westmoreland.			
		Gypseous marl, . . .	Red and white clays.	Clay-slate, . . .	unkn.		Softer slaty rocks. No organic fossils.
		Magnesian limestone, . . .	Yellow, with local deposits of shells.	Chiastolite slate, . . .	unkn.		The same, with chiastolite. No fossils.
		Marl slate, . . .	Laminated calcareous rocks.	Hornblende slate, . . .	unkn.		The same, with hornblende. No fossils.
		Rothetodteliegende, . . .	Red sandstone, with plants.				
Carboniferous System.				Mica-schist System.			
Coal, . . .	1000	Upper, . . .	All consisting of sandstones, shales, &c. with beds of coal, layers of ironstone, and deposits of plants.	Chlorite schist, with limestone,	unkn.		Quartz-rock, &c. No organic remains.
		Middle, . . .					
		Lower, . . .					
Millstone grit, ³	300	Upper, . . .	Coarse and fine sandstones, shales, coal, ironstone, &c. with plants and shells.	Mica-schist, with limestone, . . .	unkn.		Quartz rock, &c. No organic remains.
		Middle, . . .					
		Lower, . . .					
Carboniferous Limestone, ⁴	600	Yordale rocks, . . .	Limestones, grits and shales, with coal, &c. and shells.	Gneiss System.			
		Scar limestone, . . .	Very thick limestone, shelly.	Gneiss, with limestone,	unkn.		Quartz rock, mica-schist, &c. No organic remains.
		Alternating red sandstones and limestones with coal, &c. . .	In the north of England.				
Old Red Sandstone, ⁵	100 to 3300	Conglomerates and sandstone, . . .	A locally variable series of rocks, fossiliferous in the south of England.				
		Coloured marls and concretionary sandstones, . . .					
		Flagstone beds, . . .					

In the preceding table several terms have been employed which it will be necessary to explain. The whole mass of known stratified rocks is conceived to be divided into three great portions, called Primary, Secondary, and Tertiary, from the respective eras of their production: the lowest being the oldest or earliest, the uppermost being the

In the preceding table several terms have been employed which it will be necessary to explain. The whole mass of known stratified rocks is conceived to be divided into three great portions, called Primary, Secondary, and Tertiary, from the respective eras of their production: the lowest being the oldest or earliest, the uppermost being the

¹ This series is from near Bath. In Yorkshire and Sutherland it is different, as will be stated hereafter.

² As it occurs in the North of England.

³ As in Yorkshire, &c.

⁴ As in the North of England.

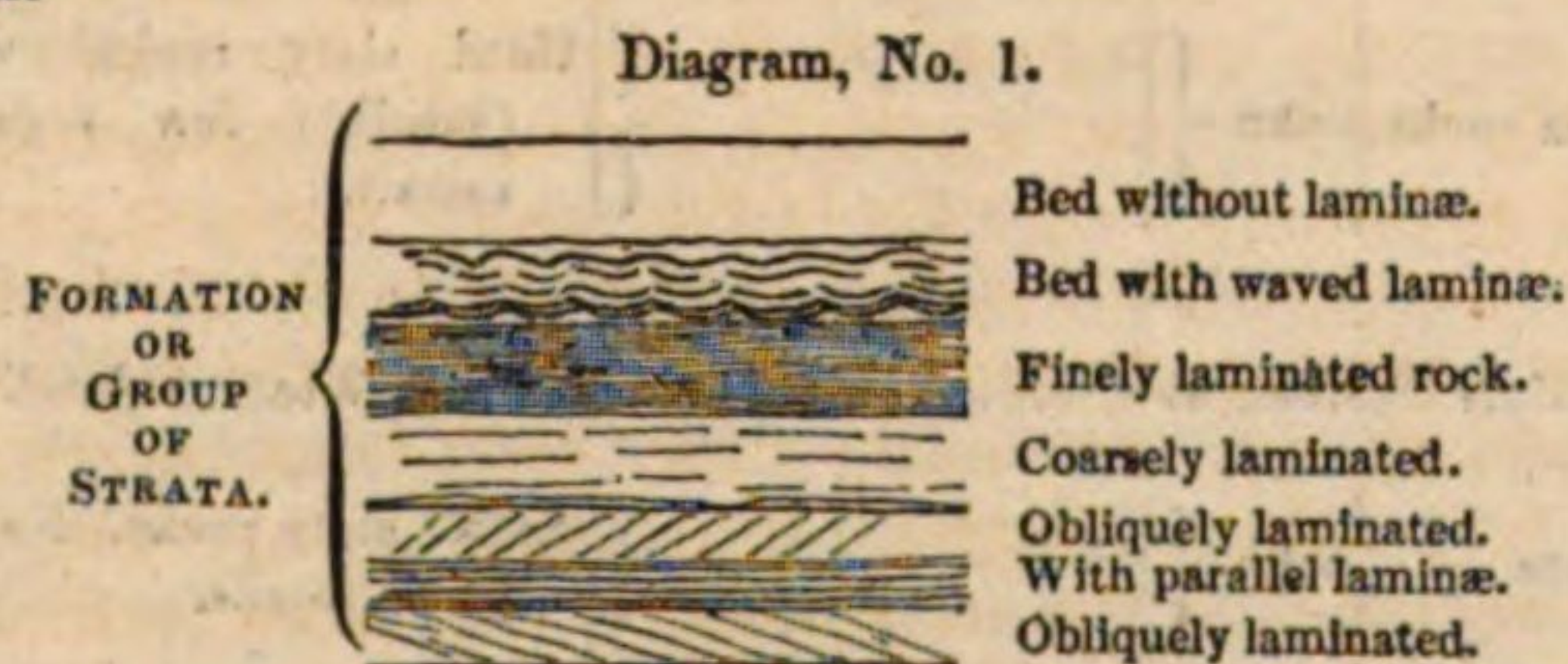
⁵ As in Herefordshire.

Geology. newest or latest. These great portions are again subdivided into systems or assemblages, named from the most characteristic kinds of rock in each; cretaceous from chalk, oolitic from oolite, carboniferous from coal, &c. or else from locality, as silurian system. The systems are composed of formations, or groups of stratified rocks, proved to have many characters in common, so as to indicate many analogies of origin; thus the chalk formation is obviously of one general type, the green sand formation contains repetitions of green and iron sands and clays, the oolitic formation is a series of oolite, sandstone, and clay in many repetitions; and so of the others.

The subdivisions of formations are not established upon similar principles in all cases; the general character of them ought to be to include each one stratified rock, as the coralline oolite, or one series of alternations of particular strata, as purbeck beds, lias limestones, variegated marls, &c.

Upon this principle all the formations of the carboniferous and other lower systems should be more subdivided; but this must be left to time, and not rashly attempted without sufficient data.

Each of the stratified rocks or series of alternations thus constituting subdivisions of formations contains one or many strata, layers, or beds; the Bath oolite, the magnesian limestone, &c. are formed of many strata or beds; and so of the others. Nor is this the last term of the analysis; for many strata, as sandstones especially, are composed of parallel laminæ, which are often separable, and bear the same relation to the stratum that this bears to a stratified rock.



SCALE OF STRATA IN OTHER COUNTRIES.

The series of strata classed in the preceding table is always recognisable, wholly or partially, in every part of the British islands; that is to say, the stratified rocks occurring in any situation can be referred to their respective types in the general table. But the local variations are considerable; several of the stratified rocks are only of limited extent; even whole formations, as the oolitic formation, change their characters, or, as the millstone grit, are entirely extinct in particular regions where the groups above and below them are complete.

This being the case, it is evident that such subdivisions are too minute and variable to be employed in comparisons between British and foreign series of strata. We must be satisfied with comparing formations and systems, and in some cases omit even these and look only to the succession of primary, secondary, and tertiary classes of rocks.

This examination has been made in almost all parts of the world, nowhere, indeed, except in Europe and certain portions of the other continents completely, yet every where sufficiently to establish the truth of the following propositions.

1. The series of British strata represents very well the succession of stratified rocks in Europe, parts of Africa, Asia, and North America; this agreement is most strict in those parts which are nearest to the British islands, and becomes more vague and indefinite as the distance increases. In France and Germany, for instance, as far as the Pyrenees and the Alps, not only the greater divisions, but nearly all the formations, most of the smaller groups, and many of the particular rocks, are well exemplified.

Geology. Round the shores of the Mediterranean analogies to the same type continually present themselves. In the basin of the Indus and on the slopes of the Himalaya mountains some of the secondary strata of Great Britain have been recognised. What is known of Australia offers less exact analogies of the same kind. In North America not only are secondary and tertiary strata known corresponding in general characters to those of Europe, but several of the European formations have been satisfactorily identified.

2. In all parts of the globe where a considerable extent of country has been surveyed stratified rocks have been found; but many small portions of the terrestrial surface are devoid of them. Stratification is, therefore, not an universal, but yet it is the most general form in which the rocky materials of the globe are accumulated.

The three great divisions of stratified rocks appear to hold the same relative position in all parts of the globe. In very distant localities the successive formations are identical, similar, or analogous, and it is evidently not unreasonable to expect from the union of observations, conducted upon one general plan, that a general history may at last be formed of all the stratified rocks in the crust of the globe, and according to the relative periods of their production.

The unstratified rocks of Great Britain, though numerous and individually variable, can yet be generally referred to a few leading divisions, according chiefly to their constituent minerals. This classification will be given hereafter; we shall now content ourselves with noticing two predominant groups of these rocks, remarkably contrasted in the circumstances of their occurrence—granitic and basaltic rocks—the former lying in great masses below all the strata, frequently in the centre of a mountain district; the latter occupying fissures in them or spreading irregularly over their surface.

Few parts of the globe except some of its vast plains and deserts are entirely deficient of rocks which are not stratified, though the surface which they occupy is not nearly so great as that covered by the strata. Granitic and basaltic rocks compose generally the greater portion of the unstratified masses, as in Britain, and lie in the same relations to the strata. For granitic rocks, throughout the globe, are the most frequent axes or centres of mountain groups, and basaltic rocks fill dykes and spread in irregular cappings over the strata. It is evident, therefore, that the structure of the exterior parts of the globe, though full of local diversity, is all formed upon one general plan, and produced by similar agencies.

GENERAL VIEW OF THE STRUCTURE OF THE CRUST OF THE GLOBE.

An observer stationed on any of the widely extended plains, which occupy so large a proportion of the surface of the earth, finds, beneath the soil and loose materials, the different rocks almost universally stratified, lying in a settled order of succession, and nearly horizontal, or gently inclined in some one direction.

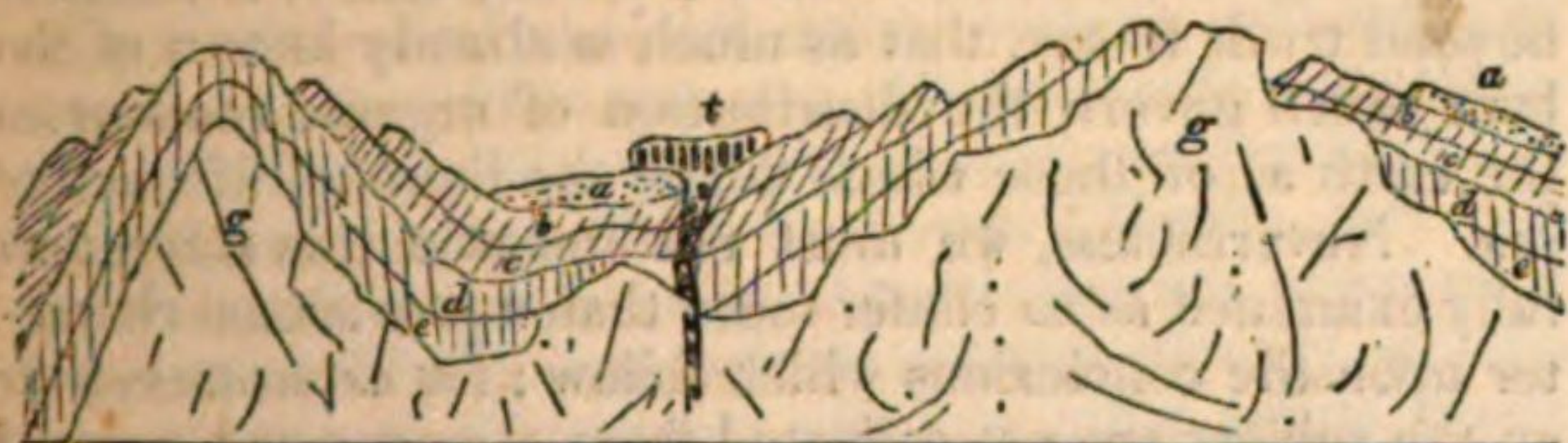
On the other hand, the high mountain districts generally exhibit in the central points, or along their axes, granitic and other unstratified rocks under all their strata, which slope away on all sides at high angles of inclination, descend to lower and still lower ground, and finally pass under the plains and more level regions, and are there covered up and buried under other superimposed strata. Very few parts of the world offer real exceptions to this general statement. The narrow mountain chains and groups occupy far less space than the wide plains which they divide, and were the surface of the continents lowered only a thousand feet, most of them would form small islands in prodigiously wide seas. Yet they are really connected together, and

Geology. all united into one system beneath, both by the unstratified rocks of the axis, and the strata of the slopes.

Let the diagram (No. 2.) be supposed a section through two mountain ranges and one intervening plain; it will be seen that the sloping strata of each mountain group are continued beneath the plain to unite with those on the other side; the strata lying in the lower countries are higher in the scale than those which rise against the mountains, and thus it happens that a person proceeding from low regions towards high districts finds strata which lay deep below gradually and successively emerge towards the mountains, and the lowest of all rise to form the highest crests and loftiest ridges. Hence also it happens that the strata are seldom quite horizontal, but generally have an inclination depending on some mountain axis. Hence also the term basin, so much used in geology, to express the sloping of strata in several directions toward a centre, a circumstance which seldom happens unless the country also agrees in geological features with the basin of the hydrographers. To discover in the plain countries the strata of the mountains, we must penetrate the earth by deep pits; but man's power is soon limited in this direction, and a much easier method is at hand for obtaining the complete section of strata existing together in any one great geological basin.

Proceeding from the point where the uppermost stratum is found, towards the borders of the basin, the country rising gradually or by undulations, the strata *a, b, c, &c.* coming out successively, may be successively examined and measured, and a section be drawn representing the whole series, till we reach the axis of the mountains composed of unstratified rocks *g*, visible in one mountain ridge, but covered in another.

Diagram, No. 2.



In this diagram, the stratified masses *ed* may be conceived to be primary strata, *cb* secondary, and *a* tertiary; *t* may shew one of the irregular overlying masses of basaltic and some other rocks. The reader will understand from this, how it happens as a general rule that the lowest strata rise to the highest ground, and the contrary.

In comparing the sections of different geological basins, a very striking general similitude prevails, but differences perpetually occur; the whole may be reduced to one general law. The lowest or primary strata, in all the mountain ranges, and throughout all the basins of the globe, have very much of a common character; gneiss, mica schist, clay-slate, quartz rock, with few or no organic remains, are the most characteristic strata of every country.

The secondary and tertiary strata, recurring mostly in lower ground, every where exhibit very similar chemical and mineralogical characters: they are composed of limestone, sandstone, and clay, with abundance of organic remains; but in distinct regions, the formations in which they naturally group themselves are rather analogous than closely related. The primary strata are the effects of almost universal agencies, accompanied by very similar local conditions; those of later date also agree in some general features, but exhibit diversities of character apparently due to diversity of local circumstances. In this sense, the primary deposits are almost universal, those of later date are more local and limited.

Origin of the Stratified Rocks.—That the stratified masses of the globe, resting upon one another in a settled order of succession, have been deposited from water in the same order as we now see them—the lowest first—the uppermost

last—is a proposition so fully and freely admitted, that it may seem unnecessary to adduce arguments in its support; but the facts which prove the watery origin of the strata open at the same time a great variety of other truths, and disclose so clearly the history of many great physical changes on the globe that a full examination of them is essential to the acquisition of right fundamental views in geology.

Nature of the Rocks.—Viewed generally, the most abundant stratified rocks may be referred, according to their chemical constitution, to one of three great groups, viz. Siliceous rocks, Siliceo-aluminous rocks, Calcareous rocks.

The secondary and tertiary series of strata consist principally of alternating strata of these qualities, and the same is less obviously true of the primary strata. If we consider on what mineralogical characters this general result depends, we find the siliceous rocks have almost universally a preponderance of the mineral quartz; the siliceo-argillaceous rocks consist of quartz with distinct or indistinct admixtures of felspar, mica, chlorite, or other minerals, containing alumina. Distinct mixtures of these minerals occur both in the primary and later classes of strata, but there is a great difference in the appearances of the compounds. Gneiss, mica-schist, &c. in the primary series, have very much the air of crystalline aggregation; the secondary and tertiary sandstones are clearly mechanical aggregates; yet upon more close scrutiny, this difference diminishes or vanishes. Several sandstones are almost crystalline, the particles of gneiss are really fragmentary; in both the parts are truly crystallized as to the interior texture, but in neither of them entirely free from the effects of some mechanical movement. The mica of gneiss is not often perfectly hexagonal as in granite, the quartz has generally lost its exact prismatic shape, the felspar its prominent angles. Exceptions to this occur certainly, but it is quite true as a general rule, and when fully investigated leads to a positive conclusion that nearly all the noncalcareous primary and secondary strata have been subjected, but in very different degrees, to mechanical agencies, like those concerned in the accumulation of common sandstone. Now the least examination of sandstone rocks, and comparison of them with the sandy and argillaceous deposits from rivers, in lakes, and on the borders of the sea, leaves no doubt that they have experienced the agitation of water; in fact, that they were sedimentary deposits.

Some limestones do and others do not yield evidence of similar agitation; they are often to be considered as aggregations of particles of carbonate of lime, slowly collected from chemical precipitation in water.

ORGANIC REMAINS IN THE STRATA.

The contents of many of the stratified rocks leave no doubt of their watery origin, and inform us besides of many circumstances concerning the condition of the waters. We find almost all the tertiary and secondary strata, and some (the upper portions) of the primary strata, rich in organic fossils of the animal and vegetable kinds; some, as zoophyta, crustacea, and mollusca, abound in particular rocks, so as to form a large part of their substance. Examined with care and all the advantages of modern science, marine, freshwater, and terrestrial plants and animals are found disposed with great regularity in the different strata, just as at the present day we find in the sandy bed of the sea and in lakes, the shelly remains of the marine and freshwater mollusca, and other creatures; and, scattered amongst them or lying distinct, some of the vegetable spoils of the land.

If we had witnessed the elevation of a part of the bed of the sea or a lake, by the force of an earthquake, and wished to remove any doubt in the minds of those who had not seen it, should we not triumphantly appeal to the

Geology. presence of marine exuviae in the one, and lacustrine shells in the other, for confirmation of the statement? Would not the argument be equally strong, the fact of the former submersion of one part under the sea, and of the other under fresh water, equally certain, from this circumstantial evidence alone, a hundred years after the occurrence?

This is the reasoning employed in modern geology: we find the greater part of the strata composing the known portion of the crust of the globe, full of the remains of marine exuviae, exactly as we should find the stratified bed of the sea at this day filled with the exuviae of now existing or lately perished animals, and we conclude, without hesitation, that the strata were deposited in the sea when the earth was in some different condition; that in fact the whole terrestrial surface of the globe was formed under water, and has since been laid dry by some natural process. Upon this clear and impregnable basis rests the whole of geological science—this is the first of its grand and impressive truths. Derived from observations over all the globe, it has been fully established in modern times, yet was not wholly overlooked in remote antiquity.

Notions of the displacement of the ocean from lands of great extent which it once covered, occur in Ovid and Strabo; the perception of its importance became general on the revival of learning in Europe, and gave rise to many hypotheses in Italy, France, England, and Germany. It is the great truth which supports the Wernerian and Huttonian theories, as well as the otherwise baseless fabrics of fancy proposed by Burnet, and Woodward, and others of our countrymen.

Besides the proof thus offered that our continents were formed under the ocean, and only recovered from it after the deposition of many strata, enclosing the remains of many races of beings, we find more limited indications of the existence of fresh water and dry land contemporaneously with the production of some of the marine strata. How is this known? By the alternation of strata containing freshwater shells and other products, or land plants, with those containing marine exuviae. Thus it is certain that while the whole or greater part of the terrestrial surface we now behold lay unborn on the bed of the primeval deep, some land did exist, some lakes or rivers held fresh water, and the air nourished vegetables and animals as well as the sea.

But the greater proportion of organic remains found in the earth is clearly of marine origin. They are incredibly numerous, often perfectly preserved, and can be directly compared with existing species of mollusca, crustacea, zoophyta, &c. so as perfectly to determine their affinity and diversity. The progress of philosophical zoology and botany is here of the highest importance: these sciences enable us in many instances to state the degree of the analogy or difference observed, and to draw some important inferences not otherwise attainable. The comparison of recent and fossil species has now gone far enough to justify some remarkable deductions.

EXTINCT GENERA AND SPECIES.

Of many thousand species of marine zoophyta, mollusca, crustacea, fishes, &c. very few can be exactly paralleled in the system of living nature, most of them are extinct, and only to be understood by the application of laws derived from the study of the most similar existing races.

The amount of resemblance between the fossil and the recent tribes is extremely variable; a few are perfectly identical; a considerable proportion so far similar as to be referred to the same genera; a still greater proportion can be included in the same great families; almost all can be referred to the same great classes of the animal and vegetable kingdoms. The differences of form and structure are thus known to be of the same order as those which at the

Geology. present day belong to the productions of different climates and different local conditions. Thus, while some very large groups of fossils have only a very faint resemblance to existing forms of life, strike us with surprise and awaken a curiosity which can only be partially gratified,—the general effect of the whole investigation is to prove a unity of design pervading the fossil and living creations,—one general system is discerned,—and the variations are referred to *differences of circumstances*. To reduce these differences of condition to some general law, let us next attend to the distribution of organic remains in the earth.

DISTRIBUTION OF ORGANIC REMAINS IN THE EARTH.

The stratified masses of the earth containing organic remains are of different antiquity, as indicated by their relative position, of different chemical and mineralogical nature, and the situations in which they occur upon the globe are various; these three circumstances influence the distribution of organic remains. In the existing economy of nature we know that marine life varies with geographical situation, and changes with the nature of the oceanic bed. But the present races of beings which become engaged among the sediments of the ocean characterize only one period: the organic remains belong to many different successive ages of the world. Thus we must examine their distribution in the earth with reference to three points,—

1. The different periods when they lived.
2. The geographical situation of the locality.
3. The different rocks which enclose them—(other things being similar).

The bare proposal of such problems for discussion is enough to prove what real progress has been made in investigating the structure of the earth; and it is scarcely beyond truth to say, that as much is already known of the laws which govern the distribution of organic remains in the earth as of those which define the limits of life in the sea. Nevertheless, we must not imagine this subject so fully examined as to confer more than a provisional character upon the conclusions which follow; for *accurate results* on the subject are yet collected from a very small part of the surface of the globe.

1. The relative antiquity of the stratified rocks is found to be, throughout most parts of the world, the circumstance of principal influence in limiting the occurrence of organic reliquiae. In every restricted tract of country, as the north or south of England, the fossil zoophyta, shells, and crustacea are different in the different systems of formations, and sometimes even in all the successive stratified rocks. Thus in the north of England the silurian system, the carboniferous system, the red sandstone system, the oolitic system, and the cretaceous system, all contain organic remains, and mostly in great plenty. Two things are here observed, first, that ALL the FOSSIL shells, &c. are clearly and completely DISTINCT from any known recent species; secondly, that with hardly one exception, all those of one system are distinct from all those of another.

2. In each system of strata lie entombed the exuviae of entirely different races of beings, all successively buried in marine sediments on the same geographical area; a series of monuments which mark the numerous changes of organic and inorganic nature. Each stratum is thus proved to have been in its turn the bed of the sea. After the deposition of a certain number constituting a formation or system of strata, all the phenomena were changed, sediments of a different nature were deposited, enclosing the remains of different races of living beings. The same things are true of equal districts in the south of England, in France, Germany, and America. It is therefore adopted as an axiom sufficiently demonstrated to be of general application, that in a limited district particular species of organic remains are distributed in certain assemblages of strata ac-

Geology. cording to their relative antiquity. Certain races of organic remains are of higher antiquity than others.

To the discovery of these sure truths Mr W. Smith has a just and recognised claim. His labours date from 1790; yet we must not omit to observe that not only Werner, but Whitehurst, Mitchell, and Lister, and others, had some knowledge of a similar kind, more, perhaps, than can be inferred from the short notices left in their works, or in the memory of their pupils.

3. But these are local truths. The attention of modern geologists, resolved to follow out the masterly researches of Mr Smith, are directed to ascertain their generality. The law just expressed may be universally true, and prove every where changes of organic life proportioned to the time elapsed, and yet not permit us to infer that these changes were contemporaneously similar over all or even a great part of the globe, *unless* the organic contents are every where similar in the same or contemporaneous formations or systems of strata. The facts yet collected on this subject are too few to allow of very precise inferences; yet it is too important to be lightly passed over. It is found that particular species of fossils have rarely, even in the same stratum, an universal diffusion. Not even over the continent of Europe can many particular species be traced at all the points of a particular rock. One *certain* belemnite (*B. mucronatus*) is almost never absent from the European chalk, and is found in no other rock; a particular trilobite (*Calymene Blumenbachii*), and a certain coral (*Catenipora Lam.*) has been found not only in most localities of the silurian limestones in Europe, but also in America; but these are rare cases. Particular genera and families are more widely distributed along the strata to which they belong; for example, belemnites and gryphææ occur every where in the cretaceous and oolitic systems, and rarely or not at all in any other systems. Orthoceratites and goniatites occur every where in the silurian and carboniferous systems, and in none which lie above. Finally, each system of strata, as far as is yet known, appears, wherever it occurs, to exhibit in its organic contents identity, affinity, or analogy with those found with it at other points nearly in the ratio of the proximity of the situations. Hence, as a general rule, it is found that the marine organic contents of each system of strata are the remains of successively created and destroyed races of animals, each of which lived through particular periods of time, and no longer; that the families and genera living at one epoch were very widely diffused, but that each species existed only in a definite and mostly very narrow geographical area.

4. Nature of the rocks.—In the modern ocean we know that the distribution of many mollusca and crustacea is influenced by the nature of the bed or shore of the sea. Oysters love a muddy bank, cockles delight in sandy shores, lobsters seek subaqueous rocks. The same dependence appears amongst organic remains; for it is too remarkable to escape ordinary attention, that the *ostrea deltoidea* is collected in immense oyster beds in the Kimmeridge clay; that an analogous genus, the gryphæa, lies in excessive abundance in the Oxford clay, and the argillaceous lias shales and limestones.

But zoophytes, as lamelliferous corals, echinida, and crinoidea, generally, are almost unknown in argillaceous rocks, unless when they are associated with calcareous portions, while they abound in many, if not all, the fossiliferous limestones.

This kind of dependence of certain races of fossil shells, &c. on the nature of the enveloping rocks, can be well studied in the oolitic and carboniferous limestone formations, where limestone, sandstone, and shales continually alternate. There is a general accordance between the different oolitic limestones in the number and general character, and often peculiar species of fossils which they contain. In respect of the fossils, the limestones differ more from

the sandstones and argillaceous strata than from each other. The same things are true in the mountain limestone series, with this addition, that the fossils are principally confined to the limestone portions of the strata.

It would appear, therefore, that the conditions of existence of certain species of fossils occurred periodically, and coincided with the deposition of particular strata, as if the dictum of Cuvier were true,—as if the oceanic fluid had changed its nature, and its depositions and inhabitants changed in proportion. But before we adopt this conclusion, we must assure ourselves of the truth of what has indeed been long taken for granted by geologists, that the marine animals lived on or near the spot where their remains lie imbedded. This does not require long discussion. The general perfection of the delicate ornaments on the surfaces of shells, echini, &c., the complete state of conservation of fishes, crustacea, &c., proves them to have undergone little or no violence, such as transporting from a distance in oceanic currents would necessarily occasion. In some cases the fossil shells, &c. have experienced the usual agitation of the shores of the sea, as in the forest marble group near Bath, the top of the oolite at Stamford, &c.; and this is of great importance in reasoning; but generally we may conclude that the doctrine is sufficiently exact which fixes the local residences of the animals near the place of sepulture of their shelly or osseous remains.

COMPARISON OF THE STRATIFIED AND UNSTRATIFIED ROCKS.

The arguments on which we rely for the proof of the subaqueous origin of all the stratified rocks may be thus summed up.

The stratified structure is that which is always assumed by successive depositions of sediments in water.

The materials (clay, sand, limestone, &c.) composing the strata of the crust of the globe, are exactly similar and in the same condition, or else very analogous, to deposits now forming under water in various parts of the globe, and similarly associated.

The organic contents of the rocks are such as admit of no other explanation, for they are mostly of marine or fresh water origin, and the few terrestrial reliquæ which occur in them shew, by various circumstances, that they were drifted from the land or overwhelmed by the sea. By combining all these considerations, we arrive at the positive conclusion *that all the really stratified rocks* are of aqueous origin.

But when we turn to the unstratified rocks the same conclusion does not apply. Independent of the universal want of this unequivocal mark of watery action (except under particular cases not really exceptional, as will appear hereafter), the following circumstances are decisive.

The materials of which the rocks are composed are neither similar to those now deposited by water nor in a similar condition. They are not composed of sands, clays, or limestone, but of a variety of crystallized minerals, many of them the same or very similar to those produced by volcanic agency, or the artificial heat of a furnace.

The association of these minerals into rocks is the same or very similar to the grouping of similar minerals in volcanic rocks. In several instances the products of volcanos and ancient unstratified rocks are identical. The variations of the different groups of rocks follow similar laws, and they occur under similar relations to the stratified rocks.

In these unstratified rocks organic remains do not occur (sometimes, indeed, portions of strata containing such remains are enveloped in unstratified rocks); and from the whole evidence no doubt remains of the igneous origin of the crystallized and other unstratified rocks.

It is very conceivable that, in particular circumstances, the effect of watery and igneous agency may be evident in the same rock. These agencies may have been contemporaneously or successively exerted; and thus combined,

Geology. successive or confused results of two entirely different agencies may occasionally lead even the experienced geologist into error. But this does not affect the principle; inaccuracies of detail must often occur in descriptions and reasonings on natural phenomena, which involve various conditions and measures of force. Already, indeed, the clew is probably obtained for elucidating the *differences* as well as the *agreements* of geological phenomena, and it is not necessary to say that no natural science can pretend to have made greater progress than this; for to know the causes of general agreement, and to discover the causes of partial diversity, is the whole problem of physical science.

Original Position of Strata.—The leading and fundamental fact of geology is the submarine origin of the stratified rocks; and the partial desiccation of the bed of the ancient sea is the general truth upon which all geological theory must be based; for in fact our examination of the structure of the existing land is nothing more than the examination of the successive deposits in the ancient ocean, varied by the effects of subterranean movements. One of the first questions which presents itself to the mind on considering this subject is this, Do we see these stratified rocks in their original state and place, or have any displacements and derangements happened to confuse their order and symmetry? The theoretical considerations connected with this question will come before us hereafter, but, for the sake of the descriptions of rocks which are to follow, it is necessary to settle the facts.

In this, fortunately, there is no great difficulty. By an investigation of the circumstances under which modern deposits happen in water, we find as a very general result, admitting of few, and those local exceptions, that these deposits ever tend to assume horizontal surfaces. Wherever the lateral influence of waves and currents agitates broad surfaces of water to a considerable portion of its depth, the earthy sediments (sand, clay, &c.), and chemical precipitates (carbonate of lime) are diffused by the movements with so much uniformity as to produce very regular strata, with a decided tendency to horizontal surfaces. Thus, all round the British islands, the very moderate slope of the bed of the sea is extremely characteristic; between the Humber and the Elbe, a distance of 4° longitude, the greatest depth is about 200 feet. (Whewell on Tides, Phil. Trans.) And, as Mr de la Beche has shewn, if the British islands and the bed of the sea around them were raised only 600 feet above their actual level (as compared with the ocean), they would be joined to the continent of Europe, and surrounded on all hands by a vast area of flat, or rather gently inclined, land; for the fall from the coast to the new sea-line would be generally so gradual as to present to the eye one great plain, uniting the western coasts of Spain, Ireland, the Hebrides, and Scandinavia.

The same horizontality of stratified deposits is observed in the dried beds of ancient and modern lakes; it is seen in every delta and along all river sides, and even if, like the stormy Arve, the rivers sweep along large masses of stone through irregular valleys, and accumulate heaps of detritus, with much local irregularity, the general result is a plane surface.

There are indeed exceptions to this general truth. One of the most interesting is that brought forward by Mr Yates in his description of the sedimentary deposits in the lakes of Switzerland. Where a river discharges sediment into deep and tranquil water, the particles, when released from the lateral impulse, are in some degree in the same circumstances as materials thrown from a loaded waggon; the coarser matters accumulate into conical heaps round the point of entrance of the river, while the finer sorts pass through greater breadths of the water and form more extensive and less inclined deposits. (Jameson's Journal, 1830.) Another case of stratified deposits deviating considerably from the horizontal, may happen when carbonate

of lime is precipitated from solution, and suffered to fall in very tranquil water on a sloping or undulated bed. The thickness of the strata produced would be greatest in the deepest parts, and the whole deposit would grow thinner towards the edges.

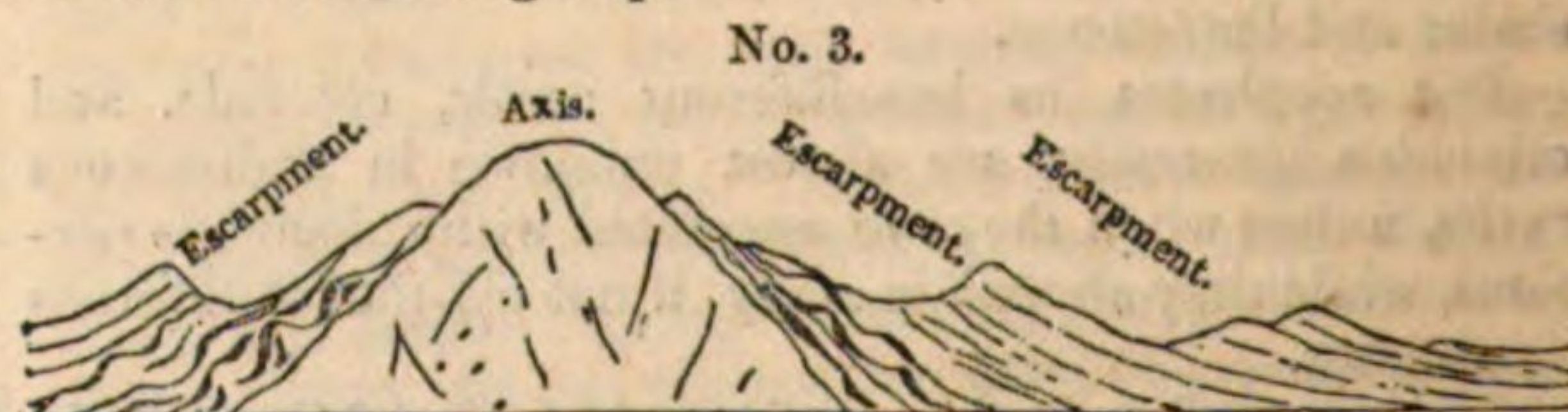
Now, in fact, among the stratified rocks which compose the crust of the globe, examples of these exceptional cases do occur; instances are really known where coarse materials to a limited extent have been deposited in inclined positions, and carbonate of lime collected in particular forms and not generally diffused; but just as in the present economy of nature we find unequivocal evidence of the generality of the law of horizontal deposition of strata, so it certainly was in the older times. We are fully convinced, that for broad and extensive formations of strata composed of various successions of sands, clays and limestones variously stored with organic remains, there can be no risk of error in assuming, as a fact sufficiently proved, that they were deposited nearly level.

Position of Strata.—Assured of this fact, as a basis of reasoning, we may proceed to inquire into the actual position of strata, as they are seen in the desiccated parts of the old oceanic bed which now compose our solid land. The most general condition of the stratified rocks of all ages is to be not quite level, but inclined to the horizon in some one direction, and at some certain angle, in each locality.

Over immense tracts of the earth's surface, the angle of inclination is extremely moderate; more than $\frac{1}{4}$ of the surface of Europe (and probably of the other continents) is occupied by strata which in common language may be said to be nearly horizontal. This character of horizontality is indeed almost exactly merited by the strata around Paris, in the Great Plains of Northern Germany and Russia, the Basin of the Danube, Hungary, &c.; but as we proceed in any direction from such centres and lines of horizontal stratification, we find the rocks to assume more and more of some prevalent inclination, so as to permit the subjacent strata to come to the surface and present escarpments in particular directions.

These escarpments commonly look toward the nearest range of mountains; in that direction the inclination of the strata augments continually, and at length on the slopes, or in the midst of such mountain range, we find them very steeply inclined, absolutely vertical, partially retroflexed, or bent into strange contortions.

Among the Alps and Pyrenees, the strata which, in every part of their surface, were originally very little inclined, and which, at a distance from the mountains, retain nearly their original position, are thrown into various disturbed positions; the local effect of violent convulsions. By a careful study of the circumstances, we observe that these indications of disturbance augment continually toward the axis or centre of the mountain group; and that the direction of the movements has there been upwards. There has, in fact, been a real and violent *elevation* of the stratified crust of the globe, corresponding to the centre or axis of each mountain group.



This truth, sufficiently attested by observation in all parts of the globe, leads directly to another very important law of the phenomena of disturbed stratification. The centre or axis of the mountain group, and consequently of the disturbing movement, is generally *seen* to be a mass of *unstratified rock*, such as granite, sienite, &c., which shews, by a variety of circumstances, that it was not deposited in wa-

ter, but rather crystallized from igneous fusion. Very often, indeed generally, proofs of its having been in a state of fusion at the time of the elevation of the strata, are found in the extension of veins of the crystallized into the sedimentary rocks, accompanied by characteristic effects of heat.

We are thus led to associate the phenomenon of the disturbance of strata, with the eruption of crystallized rock from beneath; and though the latter is indeed not exactly the *cause* of the former, but rather a concomitant effect of some general dynamical agency, geologists are not greatly to be censured who describe the phenomena as they appear, and speak of the disturbed positions of the strata, as *effects* of the elevation of unstratified rocks.

Once acquainted with this relation of the two classes of rocks, we are in possession of a clew to guide us through all the mazes of local geology; for it is equally true of small elevations of strata, as of all mountain chains, that the most general condition observable is the mutual dependence of these disturbances and irruptions of unstratified rocks.

Particular Positions of Strata.—One of the most common of the many forms in which the subterranean movements alluded to have left the strata, is that of a longitudinal ridge, from which the strata decline on both sides, usually at very high angles; this is called an *anticlinal axis*.

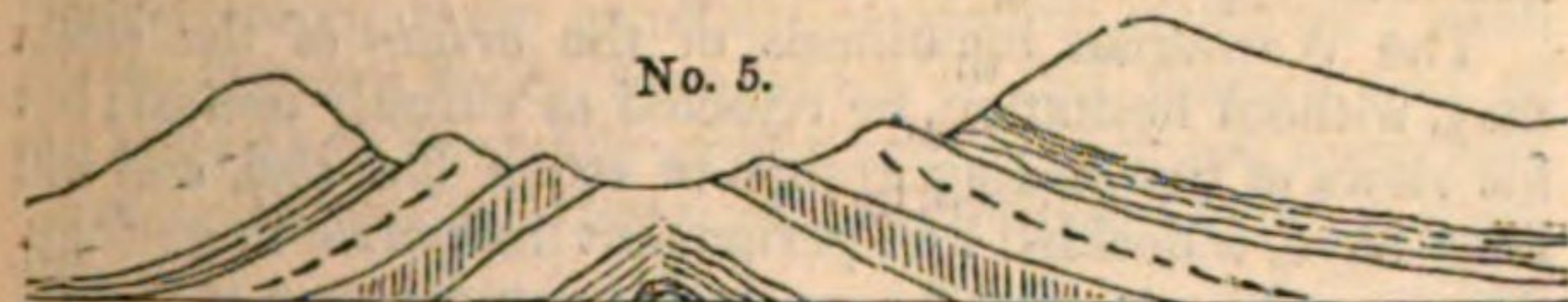
In some cases (Diagram, No. 4.) the strata are continuous

No. 4.



over the axis, as in the Ribblesdale system of faults in Yorkshire; in others (Diagram, No. 5.) they are removed along

No. 5.



the axis so as to constitute what is called a valley of elevation. The southern Cordilleras are in this state.

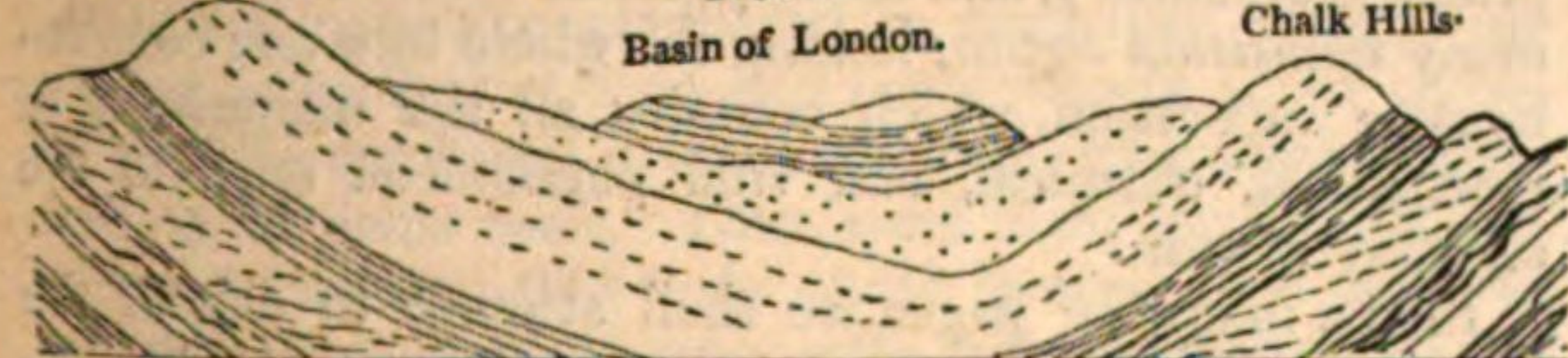
The longitudinal depression or trough (Diagram, No. 6.)

Chalk Hills.

No. 6.

Basin of London.

Chalk Hills.



towards which strata decline, is called a *synclinal axis*; this is frequently placed parallel to an anticlinal axis.

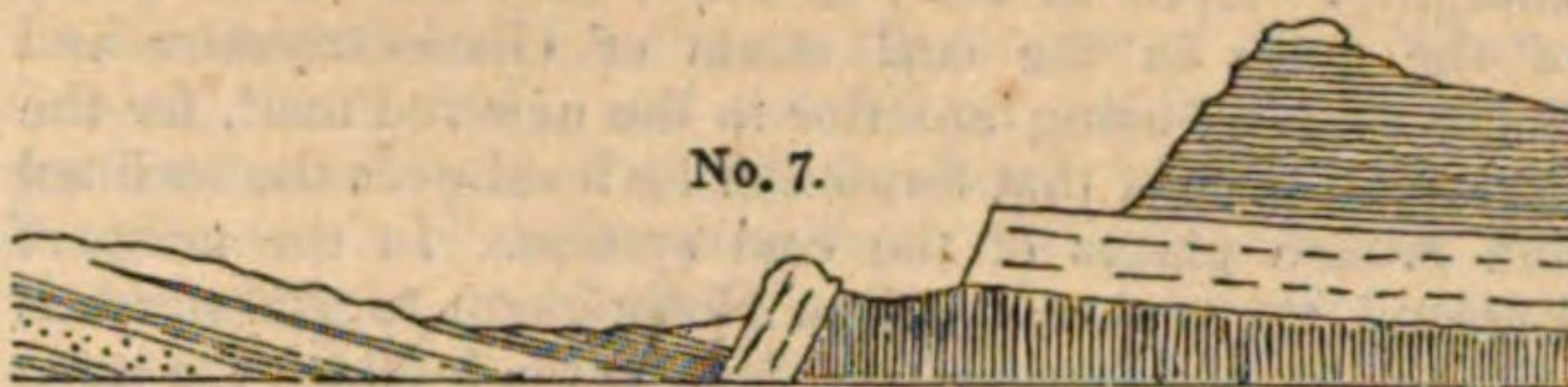
Cases of *conical elevation* do occur, but rarely; *elliptical ridges* are more frequent; and the centres and axes of such being removed more or less completely, make round or elliptical *valleys of elevation*. One of the most remarkable is that of Woolhope in Herefordshire. (Murchison.)

In some cases, instead of acclinal or declinal slopes to or from an axis, we have a complete *fracture* of the mass of strata along a vertical or inclined plane, parallel to which the beds on one side are uplifted, and on the other depressed. This is called a *fault* or *slip*; almost every coal district and mining region in the world is full of such, though their number is, upon the whole, very much greatest in elevated districts, and least in the youngest strata.

The extent of displacement on one side of such fault is sometimes only a few inches; in other cases 10, 100, or 1000 feet or yards. The great Craven fault and Cross Fell fault in the north of England¹ is complicated with a narrow

anticlinal axis, the extent of displacement produced by both is 1000, 2000, 3000, or even 4000 feet. (Diagram, No. 7.)

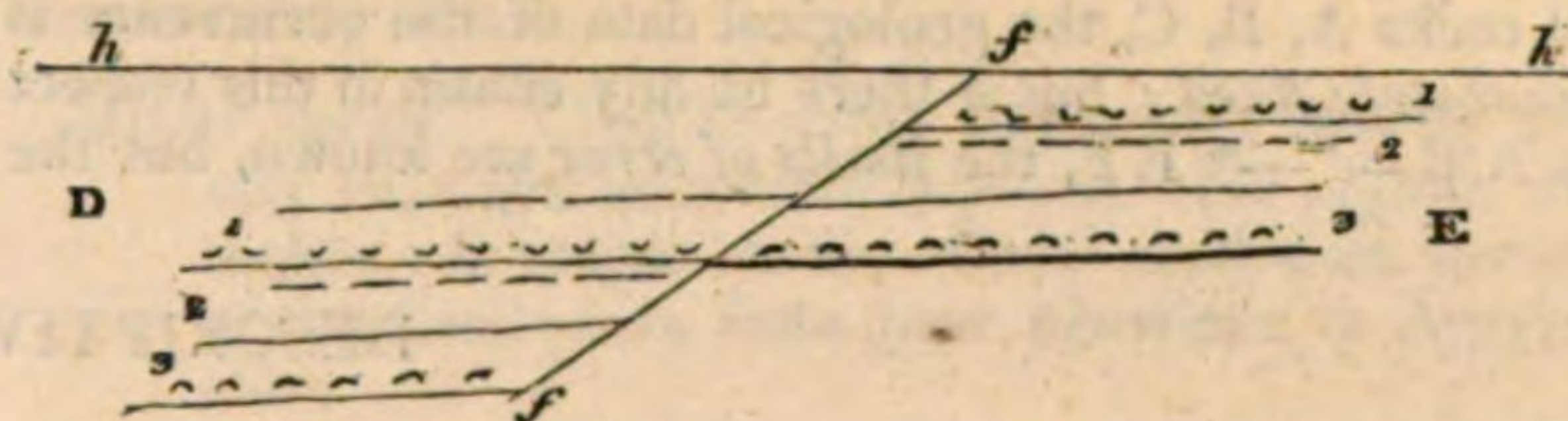
No. 7.



Irregular as seems the origin of these fractures (being occasioned certainly by pressure on planes of unequal resistance), yet some general laws of phenomena are known concerning them. The faults in any district range in many directions; yet they more specially follow two principal lines nearly at right angles to one another; they generally *cross* the anticlinal axis, and terminate in a remarkable master fault or axis of elevation.²

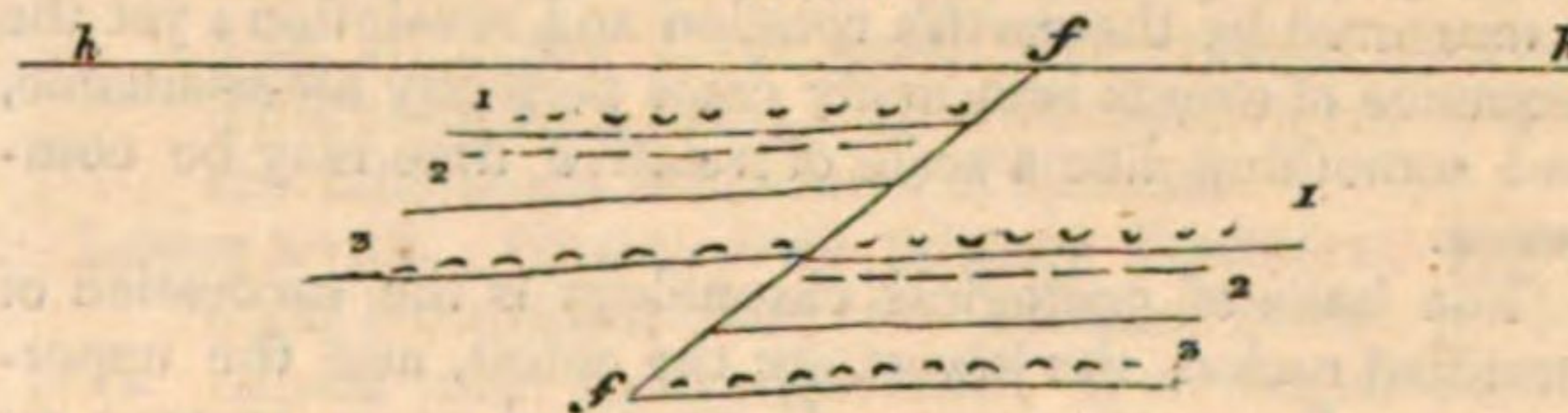
Another law has been long known to miners of the relation between the plane of the fault and displacement of the strata which it traverses; if the fault forms unequal angles with the plane of stratification, the strata are almost always found depressed on that side towards which the plane of the fault dips or declines from the horizontal. In diagram (No. 8) *h h* being a level line, *f f* the plane of the fault

No. 8.



dipping from the horizon on the side D, the strata 1, 2, 3, &c. are found (relatively) *thrown down* on the side D, and (relatively) *elevated* on the side E. Not as in the next diagram (No. 9), which represents rare and exceptional cases with the same letters.

No. 9.



Both the anticlinal axis and the fault are, without impropriety, often called *axes of (relative) elevation*.

When the violence of the disturbing agencies has been extreme, the strata are not only thrown into high angles of inclination towards or from an axis, but sometimes actually rendered vertical (as in the Isle of Wight), or even retroflexed (as in the Malvern Hills). Even a more remarkable case is common among the Alps, as in the Lake of the Four Cantons, and in the Valley of Lauterbrun, where the limestones are bent into the utmost conceivable variety of curvatures, evidently caused by great lateral and vertical pressure upon yielding materials. (Diagram, No. 10.)

No. 10.



Areas of Deposition.—The study of the various circumstances under which disturbances of the strata are manifested, has assumed a very high degree of importance since the speculations of M. de Beaumont recalled attention to

¹ See Phillips and Sedgwick in *Geol. Trans.*; also *Geol. of Yorkshire*, vol. ii.

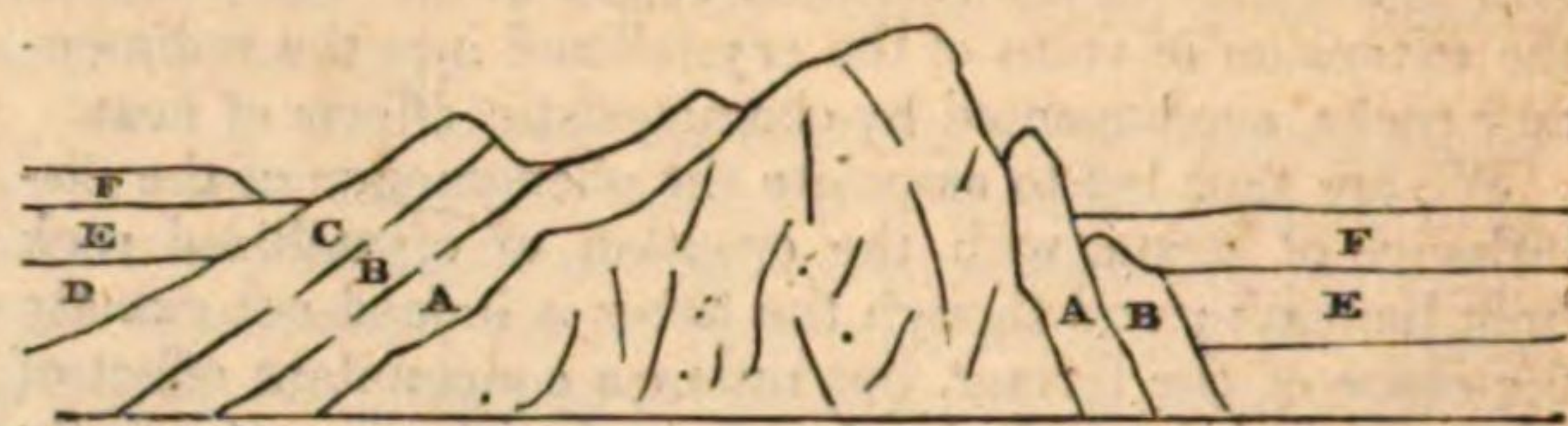
² See *Geol. of Yorkshire*, vol. ii., and Hopkins in *Cambridge Transactions*.

Geology. their connexion with general theory. It had been long known that the dislocations of the strata were of unequal antiquity. Even as early as 1791, Mr Smith found proof of the faults in the coal strata of Gloucestershire and Somersetshire, being anterior to the new red marl, for the horizontal beds of that formation lie level over the inclined and broken planes of the coal system. In the north of England, the coal-works from Nottingham to Aberford as well as those in Durham and Newcastle, indicate the same truth; but yet it is to M. de Beaumont that we owe the impulse which has given the investigation of the ages of disturbances a distinct station in geological science.

The data required for determining the geological age of a convulsion or disturbance of strata are simple, yet they cannot always be had with sufficient exactness. We must know what strata *are*, and what *are not*, displaced by the disturbance in question. If, for example, it be found that along any axis of elevation, the set of rocks included in the gneiss, mica-slate, clay-slate, and greywacke slate systems, are dislocated, but that none of the strata belonging to the carboniferous or other more recent systems have participated in the movement, the conclusion is plain, that the disturbance happened *before* the deposition of the latter rocks, but *after* the production of the former. If the undisturbed strata D, E, F be consecutive with the disturbed rocks A, B, C, the geological data of the occurrence is *accurately fixed*; but if there be any chasm in this respect as A B—*—* E F, the *limits of error* are known, but the

age of the fault is only *approximately fixed*. See Diagram Geology. No. 11.

Diagram, No. 11.



The principal difficulty, however, lies in the procurement of any really satisfactory data. If the disturbed strata be covered *along the axis* of movement by undisturbed deposits, the data must be correct, though incomplete, and the conclusion must be admitted; but this is a rare case; most frequently the observations are individually indecisive. Certain *older* strata are seen to be dislocated with reference to a certain axis; other newer beds *occurring in the vicinity* are not seen to be disturbed; if the observations can be repeated at many localities, not far removed from the axis, the negative may sometimes be sufficiently established. In such a case it generally happens that the disturbed strata are somewhere or other found unconformed in dip or in direction on the surface to those which are presumed to be undisturbed; on such evidence of unconformity, we might safely infer the geological dates of several great disturbances which have affected the Cumbrian slate district and other tracts in the north of England.

DESCRIPTIVE GEOLOGY.

LEADING DIVISIONS.

The history of the successive formation of the crust of the globe is so far like a narration of human events, that it admits of being placed in chronological order, and classed in periods more or less characteristic. Those periods are not at present reducible to the scale of historical time which is measured by the earth's rotation and revolution; yet the sequence of events is in many cases perfectly ascertainable, and something like a scale of relative time may be composed.

The basis of geological chronology is the succession of stratified rocks; the lowest are the oldest, and the uppermost are the most recent. Unstratified rocks present no such series; yet, by their connexion with the others, these also may frequently be referred to their true dates. On this account, the section of strata in any country is the foundation of all true and philosophical knowledge of its geological history.

Sufficient time has elapsed since the promulgation of the views of Werner and Smith on this subject to allow of a just estimate of their respective merits; both are amongst the brightest names in geology. The principle of *geological time* was very firmly adopted by both of these eminent men; both produced sections of strata to form the scale of geological time; Smith analyzed the English strata with masterly accuracy,—Werner grouped the rocks of Germany into large and comprehensive systems: the one established the practice of local and exact research, the other encouraged a hope of arriving at general truths. Both of these are included in modern geology.

The series of strata in Germany was grouped by Werner, who in this was guided by earlier writers, under the heads of Primitive, Transition, and Floetz or Secondary rocks, terms which have been immeasurably censured, without sufficient reason.

The primitive, or most ancient of the known strata, were supposed to be of crystalline origin, and to contain no organic remains; the secondary rocks to be mostly of sedimentary origin, and to abound in organic exuviae; the transition rocks were defined by intermediate characters.

At a later period, Cuvier and Brongniart's researches round Paris, shewed the necessity of adding an upper term to this series of systems, viz. the Tertiary strata, which Werner had little opportunity of knowing.

The Wernerian hypothesis of the *origin* of the strata may, without hesitation, be rejected as entirely useless; but his views of the leading groups of strata has had, and will long have, a decided and permanent influence in geology. The term Primitive rocks, as implying more than we know, is replaced by Primary; and Du Halloy and others have united with these the cognate Transition rocks of Werner. Thus we have at present three well understood divisions,—primary, secondary, and tertiary strata,—between which are many *transition strata*, linking the whole into one comprehensive succession, which contains all the monuments of mechanical, chemical, and vital phenomena open to the scrutiny of man.

In the following pages we shall attempt to exhibit the progress made in decyphering these monuments in the order of their inscription: this, indeed, is not the progress of *investigation*, which rather begins with the things best known, proceeds from the recognised facts and laws of diurnal geology, and gradually encounters the increasing difficulties which beset the inquiry into the ancient revolutions of nature; but our object is to state results in the smallest compass and most convenient order; and this is only to be attained by following the stream of time.

PRIMARY STRATA.

Primitive and great part of the Transition rocks of *Werner*. Inferior order of strata, *Conybeare*. Agalysian rocks, *Brongniart*.

Base of the Primary Strata.—*Inferiorly* the primary strata rest on unstratified, generally granitic rocks, so situated as to cut off all possibility of observation at greater depths. This granite floor,—this universal crystalline basis to the stratified rocks,—appears in many instances (Glen Tilt in the Highlands, Skiddaw in Cumberland, Land's

Geology. End in Cornwall, &c.) to have undergone fusion since the deposition of strata upon it, for veins pass from it into the fissures of these rocks; this may even be considered one of the most general truths yet ascertained in geology. Some theorists have proposed the hypothesis, that granite is only a fused mass of stratified rocks. To this we shall again advert, and at present shall only observe, that, whether that notion be true or false, it is enough for our present purpose that it recognises the general truth of the stratified rocks which are the products of water, resting universally on unstratified crystalline rocks, which, through whatever previous conditions their particles may have passed, have assumed their present characters from the agency of heat.

Igneous rocks, then, rest below all the aqueous deposits.

Nature of the Primary Strata.—The rocks included in this division may be referred to three principal types: Siliceous, Argillaceous, and Calcareous rocks. The most important siliceous rocks are gneiss, composed of the minerals called quartz, felspar, and mica (with or without hornblende, garnets, &c.); mica-slate, consisting of quartz and mica (with or without felspar, garnets, hornblende, &c.); quartz-rock, composed chiefly of grains of quartz agglutinated in various degrees (with or without mica, &c.); chlorite-slate, which, when highly quartzose, may be referred to this division, but, when passing to clay-slate, more naturally ranks with the next. Hornblende-slate has the same double relation. Sandstones occur in the upper parts.

The argillaceous rocks are less varied: Clay-slate, a fine grained, apparently simple, mass; greywacke-slate, of a nature intermediate between this and common sandstone; greywacke, a conglomerate of quartzose and other fragments in a basis of clay-slate; various shales.

The calcareous portions are somewhat remarkable among limestones, for their generally crystalline character; even the fossiliferous rocks have much of this feature, and all the older beds are really crystallized. (Garnet, mica, talc, hornblende, augite, quartz, &c., sometimes occur in those portions.)

Induration or consolidation to a high degree, is a general property of these strata. There is, in fact, no sand, no clay, no marl, in the whole series.

Succession of the Primary Strata. The different rocks named are naturally associated in particular groups, according to geological time, and consequently admit of being usefully combined in artificial arrangements which proceed on the same basis. Thus, amid many local variations, it is certainly true that rocks of the general type of gneiss and mica-slate lie most frequently and abundantly at the base of the whole series, and contain no organic remains; that the coarser argillaceous, sandy, and calcareous rocks, become more abundant in the upper parts of the series, and yield stores of organic exuviae, both of plants and animals. Between these extremes are found the deposits of clay-slate, chlorite-slate, &c. In consequence we have the following series of systems, or great assemblages of strata, in the primary division (*numbered according to their geological date, but placed so as to represent their relative superposition*).

3. Silurian system, sandstones, limestones, shales, &c. with many fossils.

2. Clay-slate, and greywacke-slate system, with some limestones and a few fossils.

1. Mica-slate, and gneiss system, with crystalline limestones, and few or no fossils.

1. GNEISS AND MICA-SLATE SYSTEM.

Geographical Extent.—Hardly any of the lofty mountain ranges on the face of the globe are entirely devoid of rocks of this system, uplifted upon an axis of unstratified granitic

masses, so as to be inclined at high angles to the horizon. The great European basin is defined by irregular elevations of this kind from the Frozen Sea to the Atlantic; by the Uralian and Caucasian chains, the ranges of Asia Minor, Greece, South Italy, and the Atlas; the irregular western border of Spain, Ireland, the north of Scotland, and Scandinavia, is of similar structure. Within this area, the Sierras of Spain, the Pyrenees, the Alps, and many minor mountains, shew the extremely wide expansion of this oldest known system of stratified rocks.

In the British Isles it is little known in England and Wales (about Snowdon and Skiddaw); but, in the Isle of Man, in all the very mountainous parts of Ireland (Derry, Donegal, Galway, the south-western and south-eastern districts), in the Western Isles, Zetland, and all the Highlands of Scotland, it is the predominant class of rocks.

Succession and Thickness of the Strata.—In the Highlands of Scotland the expansion of the gneiss and mica-slate system is extremely great, and the following general formula may be stated of the succession of the component rocks, it being always remembered that local variations occur, which cannot always be reduced to a regular scale in a country where no organic remains can be employed to verify the inferences from mineral character. The thickness of these rocks is very great, even to miles, but cannot be accurately stated.

Upper series. Chlorite-slates, apparently uniting the clay slate and mica-slate deposits. No organic remains. It ranges on the whole south-east border of the Grampians, from near Aberdeen to Argyleshire.

Middle series. Mica-slates, primary limestone, quartz-rock, in various combinations, the former by far the most predominant, the others only locally important; the limestone occurs in different parts of the series. That of Loch Earn, Inverary, and Balahulish, is in the upper part, approaching to chlorite-slate; that of Glen Tilt, and the vale of Loch Tay, is in the lower part. No organic remains. This occupies a great part of the eastern and southern Highlands, north-west of Ireland.

Lower series. Gneiss, with primary limestone, quartz rock, hornblende-slate, &c. Gneiss is the predominant rock, and varies much in all respects; the others are of local occurrence. Mica-slate alternates with Gneiss. No organic remains. The gneiss series occupies nearly all the Hebrides, and very large tracts of the northern and north-western Highlands.

Primary Stratification.—The stratification of primary rocks is sometimes very evident and indubitable, as in the gneiss beds about Loch Sunart in Argyleshire, the limestones of Loch Earn and Balahulish, the mica-slate of Glen Croe, the chlorite-slate of Loch Lomond: but, in many cases, it is extremely difficult to pronounce a candid and just opinion whether a particular mass of such rocks is stratified or not. This arises from the causes which are found to produce partial embarrassment even among rocks of the secondary age. These are original *peculiarities of stratification*, and subsequent *change of structure* by molecular aggregation (under the influence of heat or other general agency).

The laminar and bedded structure of gneiss, mica-slate, chlorite-slate, and primary limestone, is always more or less proportioned to the admixture of ingredients, just as in common sandstones, which are changed to flagstone by abundance of mica, but aggregated into masses of great thickness where this is absent. Besides this cause of variation, common to all siliceous and argillaceous rocks, there is a singularity in the lamination of gneiss, and the schistose

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There are, however, yet other causes which tend to confuse the evidence of stratification. In the neighbourhood of igneous rocks (granite, porphyry, &c.) the gneiss, and other similar rocks, seem to have undergone some alterations. MacCulloch assures us, that the contortion of the laminae of the rocks augments near the granite veins, quartz veins, &c., and our own observations in Argyshire lead to a partial adoption of this view. Another thing of importance has been noticed by Mr Weaver (*Geol. Trans.*) concerning *alternation* of really granitic beds with ordinary gneiss in Ireland. Whether these be *altered gneiss*, or interposed granite, is not material to the present discussion, if there be, from whatever cause, such alternations of really crystallized and sedimentary rocks, the result must be a blending of the characters of the two classes of rocks, and the stratified structure may wholly vanish in particular tracts, through the local influence of heat.

Another very general cause of difficulty in determining the stratification of primary rocks arises from the changes of structure introduced among them since their deposition. The contraction of these, as well as of other rocks, has occasioned the production of a multitude of divisional planes or joints variously related to the surfaces of stratification, and often, especially in the finer grained and laminated rocks, assuming an admirable symmetry of direction and inclination. Thus tabular and other regular structures appear in the stratified primary rocks, which arrest the attention, and add a new cause of embarrassment.

What, then, is the fruit of all this discussion? It is the conviction that the gneiss, mica-slate, primary limestone, quartz-rock, &c. are stratified rocks; the most important evidence being the alternation of these different rocks, and the lamination of different substances in them, but that the causes which tend among all rocks to complicate the stratification with new structures, have gone to the maximum in these the oldest of all; the principal of these causes being heat, either locally exhibited in the neighbourhood of igneous crystallized rocks, or generally pervading the whole mass of deposits.

Composition of Gneiss, Mica-Slate, Quartz-Rock, &c.—The views just advanced of the changes of structure superinduced on these rocks, lead us to an explanation of what seems at first an extremely perplexing circumstance in the history of primary strata,—their crystalline or pseudo-crystalline texture. Primary limestone is both stratified and crystallized. Gneiss and mica-slate are stratified, and yet they often closely resemble granite, which, because it is crystallized and not stratified, is ranked among rocks of igneous origin.

The case of limestone is soon settled. It is known, that, in contact with igneous rocks, the chalk of Ireland, and the limestone of Teesdale are turned to crystallized carbonate of lime; and experiments in the laboratory have left no doubt of the propriety of referring this crystallization of the limestone to the mere agency of *heat and pressure*.

The primary limestone is therefore crystallized, because it has been subject to high temperature, pervading, of course, all the rock with which it is associated. But it oc-

curs with nearly all members of the mica-slate and gneiss systems. All those rocks then have suffered the influence of heat.

In like manner, experimental proof has been offered by the chemist, that quartz-rock is merely sandstone altered by heat, as had been inferred from phenomena at the contact of such rocks, with the basalt and greenstone in Salisbury Craigs, Teesdale, and Shropshire; and thus we find reason to believe that some of the characters by which gneiss and mica-slate approach to granite, are owing to their having experienced considerable influence of heat. It is not, however, necessary to attribute to this heat more than the cementation of the grains of mica, quartz, felspar, &c., just as happens in quartz-rock. Some minerals may, perhaps, have been really *generated* by the heat (as happens to garnet near trap-dykes); but, in general, examination of the ingredients of gneiss, mica-slate, &c., shews the minerals to be really worn and fragmented crystals not very different from those in common sandstones, which have indeed regular internal structure, but not a regular external geometrical form. Six-sided tables of mica can seldom be seen in gneiss or mica-slate; the pyramids of quartz have lost their angles, and the prisms of felspar their edges. Sometimes, it is true, the degree of wearing which the particles have suffered is very slight, and many considerations render it probable that the circumstances under which they were accumulated, differed materially from those which produced the sediments of the secondary geological era. According to these views, then, gneiss, mica-slate, &c. &c., though really stratified rocks, present greater resemblance than others to the granite rocks, because they are composed of granitic detritus, which has been only partially water-worn, and aggregated under the influence of high temperature, which has given a peculiarity to the molecular constitution, generated new minerals, and introduced symmetrical structures, which complicate or predominate over the traces of laminar and stratified aggregation.

Absence of Organic Remains.—The opinion, early introduced into geology, that the lowest stratified rocks are deficient in organic remains still holds its ground, and still appears to support the rather questionable separation of the gneiss and mica-slate system from the superior slate deposits, under the name of primitive rocks.

MacCulloch, indeed, states that organic remains (*Orthocerata*) occur in limestone lying in the gneiss tract of Loch Eribol, in Sutherland; and in the German translation of De la Beche's Manual (by Von Dechen), we find examples quoted from Hoffman of fossils occurring among gneiss and mica-slate in the Erzgebirge and Fichtelgebirge.

The fossils lie, indeed, in greywacke; but this is stated to be really and clearly inclosed between beds of gneiss, mica-slate, &c.

A particular view on this subject has been gradually introduced into geological hypothesis, viz. that the mineral and structural character of gneiss, mica-slate, &c. is producible by long continued action of heat upon siliceous and argillaceous strata of any age. Thus in the Col de Balme the lias is supposed to have been metamorphosed into chloritic and micaceous rocks, analogous to those of the mica-slate. Those who adopt such views find it easy to escape from the difficulty presented by MacCulloch's and Hoffman's observations; but without entering on the subject at present, it is right to mention that the researches of Sedgwick and Murchison on the spot indicated by MacCulloch failed to confirm his testimony, and that in the mountainous border of the basin of Bohemia, as in every such range, *apparent enclosures of fossiliferous greywacke, between gneiss and mica-slate*, is hardly a case of sufficient importance to negative the universal result of direct researches, which all go to establish as a fact the total absence of organic remains from the whole of the gneiss and

Geology. mica-slate systems. Is this absence of all traces of organic life to be admitted as proof that the globe was at that period unfurnished with the beautiful and wonderful variety of plants and animals adapted to the land, the air, and the sea, or may we suppose such did exist, but that their reliquiae were never entombed in the rocks, or if there deposited, have been destroyed by subsequent alterations of their molecular constitution?

Igneous Rocks—Veins.—Besides the irregular granitic floor upon which all the gneiss and mica-slate system rests, and from which at many points veins or interspersed beds pass up into these strata, many other masses of pyrogenous rock have been forced among the gneiss and mica-slate, so as to constitute dykes or irregular masses of large extent. Thus porphyry, greenstone, basalt, and other crystallized rocks are found mixed with the gneiss and mica-slate in various parts of the Highlands, Hebrides, and Zetlands. Of these the most frequent is porphyry, which indeed forms a very large region in the vicinity of Ben Nevis and Glen Coe, and is also abundant in Ben Cruachan, both in great masses and in dykes variously associated with granitic veins. It is perhaps not proper to describe the serpentine of Portsoy as forming dykes, for its vertical masses appear conformable to those of the mica-slate, quartz-rock, limestone, &c. so as rather to correspond with the notion of an interposed bed.

Metalliferous veins occur, but not plentifully, in the gneiss of the Highlands. At Strontian the lead veins have been long celebrated; they range east and west and north and south: copper also occurs in the vicinity. Such veins appear still less common in the mica-slate.

2. CLAY-SLATE SYSTEM.

Geographical Extent.—Few mountainous districts are wholly devoid of argillaceous primary rocks; but these deposits are not at all to be compared in extent with the older mica-slate and gneiss formations. If we look to the continent and islands of Europe we shall find a singular reciprocity in the distribution of these members of the family of primary rocks. The gneiss and mica-slates of the Alps, Pyrenees, and mountain borders of Bohemia, are not indeed entirely unaccompanied by such argillaceous deposits, any more than the Scandinavian and Highland chains, and the north-western primary tract of Ireland; but the principal masses of the clay-slate system lie apart in the Harz and the Ardennes, in Brittany and Cornwall, the Welsh and the Cumbrian mountains, and the ranges of the Lammermuir and Donegal; yet under all these slate tracts lies the fundamental granite, and similar veins pass from it into the argillaceous covering. In some parts, as in Cumberland (Skiddaw), and in the Isle of Anglesea, slight traces of older rocks separate the clay-slate from the granites, but the general fact appears to be that the deposition of the two systems was influenced by different physical conditions related to different geographical centres.

Succession and Thickness.—The districts of Britain in which the clay-slate system unfolds into the greatest variety of formations are the Cumbrian region and North Wales. The recent researches of Sedgwick and Murchison in Wales permit us to unite the sections of the principality with those of Cumberland, and thus to offer a nearly complete series of the members of this great mass of deposits. As before we place the groups in the order of *superposition*.

Upper Group, or Cambrian Rocks (Sedgwick), consisting of

Plinlymmon Rocks.—Hard, fine, sandy, or coarse greywacke and greywacke-slate (without organic remains?), which is locally productive of roofing slates, and generally traversed by an extraordinary abundance of symmetrical fissures. Wales, Cumberland, and Westmoreland, the Lammermuir Mountains, Donegal Ranges, borders of Dartmoor,

North Devon, Charnwood Forest. Thickness in the Cumbrian tract 3000 feet at least.

Bala Limestone.—Dark, slaty, calcareous rock, variously associated with the slate, and locally rich in organic remains, both in Wales and Westmoreland. Limestone of Ilfracombe and North Devon? of the Harz, Norway, Brittany, &c.? Thickness in Westmoreland 100 feet.

Snowdon Rocks.—In this division are rocks of various colours, green, blue, purple, &c., and fine or coarse grain. Good roofing-slate abounds, and the peculiar fissility called *cleavage*, on which it depends, is very general in all the mass of rocks, which are some thousand feet thick both in Wales and Cumberland. In both districts also the sedimentary rocks are much intermixed with porphyries and greenstones, both in seeming beds and dykes, and many parts of the slaty rocks themselves are really amygdaloidal, or else composed of fragments of porphyry and other igneous rocks. No organic remains have been found in the Cumbrian district, but they occur in Snowdon. Thickness in Cumberland 3000 feet at least.

Lower Group, or Cumbrian Rocks (Sedgwick).

Clay-Slate.—This is a singularly uniform mass of laminated argillaceous rock, of a dark colour and smooth texture, with vertical cleavage and symmetrical joints. It is devoid of organic remains.

Chiaistolite-Slate differs hardly at all from the preceding, except by including crystals of chiaistolite and hornblende.

Hornblende-Slate.—This is very different from the rock so named in Glen Tilt, for its basis is clay-slate with intermixed crystals of hornblende or actynolite.

These three divisions may be above 3000 feet thick in Cumberland.

Stratification.—This structure is very evident in some parts of the clay-slate system, but very indistinct in others. Thus in Cumberland it would be a difficult thing to say what were the planes of stratification in the Skiddaw slates, but for the assistance of the chiaistolite slates beneath, and the red argillaceous rocks of Derwentwater above. The planes of stratification thus judged of appear to rise to the north-west toward an axis passing from Caldbeck Fells south-west to Egremont. The same direction and dip of strata is to be inferred from the interposed limestone beds of Coniston Water Head (Bala limestone), and it is confirmed by minute examination of the alternation and gradation, of the different sorts of slate.

But, certainly, on a *general view* of the country, the stratified structure is far from evident; so that many persons, impressed by the remarkable structure called cleavage which traverses nearly in vertical planes the surfaces of stratification, and the symmetrical joints which divide the rock into prismatic masses almost of geometrical regularity, leave the district under the impression that it is not at all stratified.

The same remarks apply to the slaty tracts of Cornwall and Wales, in which, especially the latter, both cleavage planes and symmetrical joints predominate over the stratification. That these structures are of later date than the stratified structure, is evident when we compare primary and secondary districts, for in the latter symmetrical joints pass through imbedded organic remains, and through many alternating sedimentary strata.

They are in fact superposed structures, and from what is known of the introduction of similar structures into ordinary clays and shales by the side and in the vicinity of igneous rocks, independent of general considerations, such as the high degree of induration of these rocks, there is little doubt that the agency of heat is the general cause of these phenomena of structure. Argillaceous slaty rocks deposited from water, like common clays and shales, still retain traces of their original stratification, but they have

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Geology. undergone *generally* those changes depending on pervading heat, which later secondary rocks of similar original nature have experienced *locally* near the granitic region of the Col de Balme, near the Whin-Sill of Teesdale, and the whin-dyke of Coley Hill.

The *Chemical and Mineralogical* composition of these rocks is very analogous to that of common clays and shales; but the frequent admixture of igneous rocks, both in interposed beds and dykes, and the local metamorphism of the slate rocks, so as to assume amygdaloidal (Cumberland) and porphyritic (North Wales, Cornwall) structures, renders their exact origin a very interesting and unsettled subject of speculation.

Organic Remains, as previously observed, are (except in Snowdon and at Tintagel in Cornwall) almost confined to the limestones which inter laminate the slates. These are yet very imperfectly known. In the Cumbrian limestone occur calamopora, lithodendra, cyathophylla, orbicula, and, we believe, a much greater variety in the limestone of Bala. Some organic remains also occur in the coeval limestones of Devonshire. The Norwegian limestones, probably coeval, are by far richer in the zoophyta, crinoidea, and conchifera.

Igneous Rocks, Veins, &c.—Granites, sienites, porphyries, and greenstones, are plentifully associated with the slaty rocks of Cumberland and Westmoreland, about Helvyllyn, High Pike, Borrowdale, Wastwater, Ennerdale, &c., the granitic rocks, generally in great masses, which have burst through the slates,—the porphyries and greenstones often interposed in partially conformable layers or passing through the rocks in dykes. Similar facts occur in the Lammermuir, in the Snowdon ranges, and the slates of Cornwall and Brittany; and in many cases the porphyritic beds have been subjected to the same disturbances as the slates in which they are interpolated.

The mineral veins of the Cumberland district pass generally east and west (rarely north and south), and yield sulphuret, carbonate, phosphate, arseniate, &c. of lead; sulphuret, carbonate, arseniate, &c. of copper; ores of iron, zinc, manganese, &c.

Those of Cornwall and Brittany have generally east and west courses, and north and south cross courses, with intermediate or quarter point veins. Ores of copper, tin, lead, silver, cobalt, antimony, bismuth, &c. abound in the rich tract of Cornwall. Similar statements apply to Brittany. The Snowdon and Cardiganshire chains yield lead and copper ores, also in east and west veins principally. The Harz is also a very metalliferous range.

It appears to be true as a general rule, that it is the Snowdon series or lower division of the Cambrian group which in Wales and Cumberland is the most highly metalliferous. In Cornwall, the lower portions are the richest, but nowhere, we believe, is the uppermost series of Plymmon rocks remarkably rich in metallic veins; for example, the Lammermuir, the south-east of Westmoreland, Charnwood Forest, the middle of Wales, part of the upper slates of Cornwall and Devon.

3. SILURIAN SYSTEM.

Geographical Extent.—It is to the labours of Mr Murchison, in South Wales and the bordering counties, that we are indebted for a clear knowledge of the relations of this great mass of rocks, which were but partially noticed, and never consistently arranged by preceding writers. It is still to the district which he has worked, and specially to the counties of Hereford, Radnor, Brecon, Carmarthen, and Pembroke, that we must look for the most complete development of it yet made known. It does occur in Westmoreland and the Craven district of Yorkshire, and probably also in the southern primary tract of Ireland, between Waterford and Bantry Bay. There appears good reason to believe that part of the slaty rocks and limestones

of the Harz and Norway, as well as the Eifel limestones, belong to it. Judging from organic remains which we have seen, it appears not unlikely that large tracts in the northern parts of the United States and Canada belong to this system.

Succession of Deposits and Thickness.—Mr Murchison's views on this subject, after mature reflection, appear finally to have settled into the following intelligible classification, which, however, can only be considered as *locally* applicable until the more extensive investigation which these rocks deserve in other districts, shall determine the general characters of the deposits. The order is that of *superposition*.

Upper silurian system, consisting of—

The Ludlow rocks, 2000 feet in thickness, which are composed of three groups, viz.

- h. Upper Ludlow rock, an assemblage of slightly micaceous, grey, thin bedded limestones and shaly beds, containing a very great abundance of fossil shells, chiefly belonging to brachiopoda; some trilobites occur in it.
- g. Aymestry limestone, a subcrystalline grey and blue argillaceous limestone, full of pentamerus Knightii, and other brachiopoda; some corals also occur.
- f. Lower Ludlow rock, a series of sandy, liver, and dark-coloured shale and flag, with concretions of earthy limestone; the organic remains are various and numerous.

The Wenlock rocks, &c. 1800 feet thick, including—

- e. Wenlock limestone, a highly concretionary grey and blue subcrystalline limestone, singularly rich in particular genera of corals and crinoidea, brachiopoda; certain gasteropoda and polythalamie cephalopoda, and trilobites, are very plentiful in the Welsh, Salopian, and Dudley limestone, the same species occurring also in the Eifel and partially in the Harz, Norway, Russia, Brittany, and North America.
- d. Wenlock shale, a liver and dark grey-coloured rarely micaceous shale, with nodules of earthy limestone; trilobites, brachiopoda, orthocerata, &c. occur in it.

Lower silurian system, consisting of—

The Caradoc rocks, 2500 feet thick.

- c. Thin bedded, impure, shelly limestone, and finely laminated, slightly micaceous, greenish sandstone; with pentameri and other brachiopoda.
- b. Thick bedded, red, purple, green, and white freestone, conglomeritic quartzose grits, sandy and gritty limestones, brachiopoda, trilobites, &c.

The Llandeilo rocks, 1200 feet thick.

- a. Dark coloured flags, mostly calcareous, with some sandstone and slate. Asaphus Buchii, and other trilobites.

In tracing from Shropshire and Radnorshire the courses of these various rocks to the west, it is found that the limestones lose their thickness and importance, and the distinctions of the several groups becomes, from that and other causes, less easily followed. This variation of numerical division is common to all the systems of stratified rocks: it leads us to doubt the applicability of minute subdivisions, however well conceived and locally exact, except for small geographical areas. In searching for the continuity of such systems we may conveniently follow rather such leading divisions as upper and lower silurians, though it is very probable that these will be often undistinguishable, especially as the development of the limestones (which in this, as in all other stratified systems, offer the most decided characters) is unequal and irregular.

STRATIFICATION AND ORGANIC REMAINS.

At this stage in the series of deposited rocks, all doubts and difficulties as to the fact of their complete stratification vanish entirely. In the alternation of sandstones, shales, and limestones, many of them fossiliferous, the fossil shells

Geology. and crustacea, &c. differing in the different groups, what do we recognise but the very same principle as that which was detected by Mr Smith's researches among the oolites of Bath? *It is this close analogy* between deposits so far distant in geological date as the superior primary and middle secondary rocks, which constitutes the great interest of Mr Murchison's researches. We, who have known, step by step, the whole progress of his researches, claim the results as being peculiarly illustrative of the modern school of geology, which in all its investigations strives to detect, by a close inquiry into certain classes of phenomena among rocks of different ages, the unchangeable influences of nature. But there is another point of view in which the silurian system demands our especial attention.

It appears highly probable that the organic remains of this ancient system are sufficiently numerous to justify satisfactory inferences on points of the greatest importance in the philosophy of geology.

In the first place, we must observe that these reliquiae, though perhaps specifically different from those in the older limestones and other fossiliferous rocks of the clay-slate system, are mostly congeneric, of analogous structure, and similarly distinct from existing forms of life. There is evidently such an agreement of mineral and organic characters between the silurian and clay-slate systems, that both must be admitted to have been deposited under circumstances depending on the same or very similar physical conditions. That system is so linked with the mica-slate and gneiss, that the whole mass of primary strata may be conceived to be the result of physical conditions, gradually or periodically variable, but not suddenly interrupted. It appears that, in the deposition of the subcrystalline gneiss and mica-slate rocks, mechanical agitation of the ocean was rare and slight; and that, on the contrary, in the highest group of the primary strata, the sandstones and conglomerates indicate frequent and considerable watery disturbance.

Nearly in the same ratio, the monuments of organic life appear and grow numerous, the limestone bands become more regular and continuous, the stratification less complicated by superimposed structures, and the *characters of secondary strata appear*.

It was therefore not unphilosophical in Werner to propose for these formations, and some of those already ranked in the clay-slate system, the term *Transition rocks*: such in truth they are; yet the term will probably fall into disuse, because the enlarged views of modern geologists have led them to recognise in all the varied mass of stratified rocks, only one long, though locally interrupted, series, every term of which is really *transitive*, connecting the earlier and later formations. Of this abundant proof will be found by every inquiring geologist.

The organic remains of the silurian system are most abundant in the limestones (*e. g.* Wenlock and Aymestry limestone); in calcareo-argillaceous layers (*e. g.* Builth and Llandeilo flags); or in layers of shale and sandstone associated with such calcareous deposits. The same is true (in a general sense) in the secondary strata, and, as far as examples can be quoted, it is also true in the lowest primary strata. The remains of polypiferous zoophyta, occur almost exclusively in the limestones; this is true for all the primary strata. The corals of the Wenlock and Dudley limestone, and those of the contemporaneous limestone of the Eifel, are aggregated in such forms as to suggest, though perhaps not to establish, the notion of these rocks being in fact ancient coral reefs. Crinoidea are less plentiful in these limestones than in some of later date: the brachiopoda and other mollusca, and also the trilobites, occur in the calcareous, argillaceous, and arenaceous rocks. Remains of fishes have been observed, even abundantly, but no traces of reptiles.

The character of induration or consolidation is less remarkable in these strata, than in all the rest of the primary rocks.

Geology. The sandstones are, however, seldom soft; the argillaceous beds are shaly or slaty, and the limestones still subcrystalline.

Igneous rocks are associated with different parts of the silurian system, under circumstances of great interest, though the geological date of their irruption can seldom be determined exactly. Mr Murchison, in describing them, adopts the convenient plan of referring them to their several parallel anticlinal or disruptive axes, and characterizing the nature of the igneous rocks and their effects upon the neighbouring strata. North of the Severn, Lilleshall Hill, the Wrekin, Charlton Hill, &c. mark parallel axes ranging from N.E. to S.W. and piercing through beds chiefly of the Caradoc rocks, the sandstones of which are converted to quartz-rocks at the point of junction of the trap. The ridge of Caer Caradoc contains many varieties of felspar rock, granite, and greenstone, and actynolitic amygdaloid.

On the flank of this axis of violent elevation, sandstones are converted to quartz-rocks, and particular strata occur composed of the materials of igneous rocks, the origin of which the author ascribes to subsidence of volcanic matter in water, and calls *volcanic sandstone*.

The mining district of Shelve, is an isolated tract separated from the Linley and Longmynd Hills by the remarkable ridge of quartz-rock, called the Stiperstones. It is made up of parallel ridges of trap and alternating depressions in the lower silurian rocks. Some of these trappean rocks alternate conformably with the stratified deposits, and are supposed to be of contemporaneous origin, and partly of the nature of the volcanic sandstone previously noticed; others are of the ordinary character of irrupted trap. Veins of lead-ore occur in the greywacke, near the junction with the trap.

The Breiddin Hills are formed in ridges running from E.N.E. to W.S.W. The eastern, or chief ridge, contains compact felspar rocks, slates, porphyries, greenstone, &c. they burst through upper silurian rocks. The other main ridge contains chiefly columnar greenstone.

The Old Radnor group contains abundance of hypersthene, and passes from this to a fine grained greenstone. Near Old Radnor church, the upper silurian rocks are dislocated, and bands of imperfect serpentine occur between the trap and the limestone, which near the contact is wholly unstratified, crystalline, and hard; the shale is also hardened to a slaty substance: coatings and nests of anthracite, with minute metallic veins, appear near the junction. Other groups of trap, near Builth, range from N.E. to S.W., and resemble in many respects the rocks of the Shelve district. Other occurrences are noticed in Brecknockshire and Caermarthenshire, and from the whole investigation, we find in the rocks which have been irrupted into these silurian strata, in their effects on the surrounding strata, in the alternation of pseudo-volcanic sandstones, and in the mineral springs which accompany the ridges of trap, not only the usual analogies to the effects of heat, but special resemblances to that form of the igneous action which is exemplified in volcanos. The facts are generally of the same order as those noticed among the older slates of the Lammermuir, Cumbria, Snowdonia, but more exactly and definitely traceable.

The circumstance of the dependence of the metallic veins on the axis of igneous rocks, in the Shelve district, is an example on a small and distinct scale of what is seen in Cumberland, Snowdonia, and most of the great mountain chains of Europe (of all geological ages). For it is a general truth, that metallic veins abound in proportion to the proximity of the situation to axes of dislocation, and irruptions of pyrogenous rock—a view first positively advanced by M. Necker.

GENERAL VIEWS CONCERNING PRIMARY STRATA.

The primary formations have so much of parallelism to each other, so much conformity of position, as to indicate

Geology. long periods undisturbed by great convulsions. It is true, that among the old slates of Cumberland, between the Skiddaw and Snowdon series, a red conglomerate rock occurs, and seems to prove local disturbance; but this solitary exception rather suggests the commencement of that volcanic agency which in the period of the deposition of the Borrowdale and Langdale slates was very frequently exerted. Among the silurian rocks, conglomerates also occur, and seem to imply that part of the older Snowdonian and other slaty rocks were previously raised up to be exposed to atmospheric action; but yet the conformity of the silurian and Plynlimmon rocks, seems to forbid the notion of any *great convulsions*, though it may not at all affect the question of *gradual elevation* of part of the older rocks.

However, it is certain, that in the later part of the primary period, or perhaps after its close, great and general disturbances happened, which in many parts altered the aspect of the globe, by raising up large tracts of land, and dividing the expanded ocean by a multitude of mountainous islands. Without entering into a wide field of inexact discussion, we may dwell on some facts of this nature which have come to light concerning the ancient hydrography of the British islands.

It is remarked of the Grampians, that their elevated ranges no where include any masses of secondary strata, though round their flanks these rocks spread very widely and on all sides; they rest on the gneiss of Sutherland, mica-slate of Argyleshire, chlorite slates of Perthshire, &c. and in general appear in such relations to the ancient rocks as to indicate that these had stood up above the ocean in which the carboniferous system was afterwards formed.

In studying the Lammermuir ranges, which are composed of slaty rocks less ancient than any in the Highland chains, the same old red sandstone border is found as that which encircles the Grampians, and under the same relations. These mountains, then, were also raised, though not to their present elevations, before the commencement of the carboniferous era. Now, it is very remarkable, that the Grampians and Lammermuirs are nearly parallel, both ranging nearly north-east: both are prolonged (across the channel) into Ireland, the former reaching Donegal, and the north-western projection of Ireland, the latter entering by Donaghadee on the eastern coast of Ireland, and proceeding inland to Cavan. In Ireland these prolonged ranges also shew the same independence of the carboniferous deposits; and the same results apply to the south-east border of the island.

Again, the same north-east range accompanies the slaty rocks of the Isle of Man, and it is recognised in a very distinct manner in the insulated and romantic district of the English Lakes. The axis of these slaty tracts passes north-east and south-west; and the nearly circular mass of primary strata is begirt by a belt of later red sandstone, limestone, &c., all evidently unconformed to the axis of the slates. The date of one of the elevations of the Cumbrian slates is thus probably fixed before the commencement of the carboniferous era.

The slaty ranges of North Wales have the same direction, north-east and south-west; they are also, probably, or rather certainly, anterior in elevation to the commencement of the carboniferous epoch; and, finally, the axis of the Cornish and South Devon slates has the same general direction, and these rocks, probably, were elevated before the deposition of the carboniferous system.

Most of these mountains have an axis of granite and other pyrogenous rocks. Thus, a great number of parallel mountain ranges were produced by disturbing movements within one geological period, the result being, in each case, one, or a number of anticlinal axes, in each physical region, parallel to each other. It is impossible not to be struck with the probability thus arising, that, in the direc-

Geology. tion of convulsive movements, some regular laws are discoverable. In fact, if we were to be satisfied with one instance, this north-east direction among so many presumed contemporaneous elevations, would establish the truth of Elie du Beaumont's hypothesis, which would have us recognise, as a principle capable of practical application, that parallel mountain ranges belong to the same era, and the same exertion of disturbing forces. This must be, however, subjected to further and more rigorous trials before it can be adopted among the admitted generalizations of inductive geology.

Though it thus appears evident that many of the most marking characters of British physical geography have so old a date as disturbances anterior to the carboniferous system, yet, on the continent of Europe, this is by no means the case; for the Alps, Pyrenees, Carpathians, and Apennines, are of more recent date, and, at the time when the Grampians sent streams and detritus to straits where now the valleys of the Forth and Clyde meet, the greater part of Europe was a wide ocean.

The state of the globe during the period of the production of the primary strata may never be fully disclosed by geological inquiries, aided by higher departments of knowledge: yet, as a view of the successive conditions of the globe, however imperfect, constitutes the very essence of philosophical geology, it is necessary to ascertain what progress has been made in this dark research into some of the earliest natural records of creation. It is remarkable that the lowest of all the known systems of stratified deposits should be at once the most extensive, the most nearly universal, the most uniform in mineral character, the only one from which organic life appears to be totally excluded, and in which the character of mechanical aggregation is the most obscure. Most of the circumstances are original, though the latter has been apparently influenced by superposed structures, due to subsequent agencies. Can we hesitate to admit that the globe was then in a condition which has never since occurred to it? Does it not strike the mind as a reasonable hypothesis, that the ocean was, during the period when gneiss and mica-slate were formed, unfitted, by some peculiarity of condition, for the support of living beings? Such peculiarity, to judge from the deposited rocks, was not of a chemical nature; for these are not of a description to countenance such an opinion, on the contrary, the gradual introduction of fossil exuviae in the superior strata, till at length, as we ascend in the scale of rocks, they are unfolded in great abundance, seems to point to some slow change of a pervading physical condition.

In accordance with the undoubted truth of the general expansion of rocks of igneous origin below all the stratified masses, we naturally inquire if the agency of subterranean heat is of a kind to account for the phenomena observed. It is obvious that, when and wherever the supposed high subterranean temperature was applied most directly to the base of the ocean, so high a temperature would be maintained therein, as to be incompatible with the existence of organic beings; changes would be produced upon the igneous rocks in an expanded thermal (agitated) ocean, quite different from those occasioned by lateral movements in later times through narrower channels of cooler water.

It does not appear improbable that a hydrothermic action, of the nature suggested, may be found sufficient to account for the remarkable resemblance between the (primitive) granitic, and the (derivative) gneiss rocks,—their almost universal diffusion,—the singular undulated lamination, rather than stratification, which belongs to so many of the older primary rocks,—and the absence of organic life; while, as the form of the globe was changed by subterranean disturbances, and mechanical agencies arose to importance, the sea received partial deposits from emerging lands into its contracted and variously ramified basins, and the communication of heat from below was sufficiently re-

Geology. tarded by the intervention of solid rocks (gneiss, &c.) to allow, at least partially, temperatures suited to particular races of animals. It appears somewhat in favour of this view that the races of animals are, for the most part, very peculiar,—their association with abundance of corals seems to justify a belief that they were suited to a warm climate,—and the disappearance of nearly all these genera and families, after passing through a few more formations and systems of strata, is at least in harmony with the conditions assumed.

But this hypothesis, suggested by consideration of the phenomena, assumes quite another character, when compared with deductions from the admitted fact of the former igneous fluidity of the mass of the globe. From that important truth, as we deem it, it seems to follow necessarily that the globe should pass through many stages and changes before, in any part of the surface, the conditions could be obtained, within which the Almighty Architect of the universe has seen fit to restrict the exhibition of organic life. One of the most direct and important of these, and the most obviously influential on mechanical, chemical, and vital phenomena, is the diminution of surface temperature: this having arrived, locally or generally, at a certain point, the unchangeable laws of nature relating to organic life, which are but the expression of the will of God, began to operate; and it is not one of the least curious of the adjustments of the terrestrial creation, that the diminution of the surface temperature is limited. A certain point once reached, the prescribed conditions of organic life once attained, they assume a character of stability,—a regularity of effects which enables a finite but intelligent being to trace them back toward their origin.

SECONDARY STRATA.

Base of the Strata.—In consequence of the disturbing movements already alluded to, which have broken up the primary rocks into various irregular masses, and in places thrown them off entirely from granitic nuclei and axes, the secondary strata have not always, nor indeed generally, their surfaces parallel to those of the primary age. On the contrary, the two classes of rocks are unconformed to each other; so that the same secondary strata may rest in some part of their range on gneiss, in other parts on clay-slate or silurian rocks, or, without any such intervention, on granite, according as these rocks, after the convulsive displacement of the crust of the globe, formed respectively the bed of the sea.

As a general but not universal fact, it is found that in the vicinity of elevated mountain masses the secondary strata are more nearly horizontal than the primary; hence they were included by Werner in his class of floetz or flat-lying rocks: but this classification, founded on a geological accident, is not satisfactory, though in fact it agrees nearly with the modern divisions.

Nature of the Secondary Strata.—They consist of three sorts of rocks, deriving their most prominent characters from three particular substances, viz. Siliceous, Argillaceous, and Calcareous rocks. On comparing them respectively with the corresponding forms of the primary series, little if any chemical difference can be established between the two classes. In the constituent minerals of the siliceous and argillaceous rocks also a great resemblance prevails. It is still quartz which constitutes the great bulk of the masses. Mica interlaminates many sandstones, and felspar varies the substances of others. Some clays are but a finer and more argillaceous kind of sandstone, just as some clay-slates are not obviously distinct from an argillaceous form of mica-slate. But yet, on a close comparison, we find the condition of these mineral ingredients somewhat different: the grains of quartz, mica, and felspar are in fact more worn on the surfaces, more broken and fragmentary in the secondary than in the primary strata. Also the aggrega-

tion of them is so far different, that the influence of sedimentary aggregation is extremely evident in all the secondary strata. The degree of consolidation of the mass is generally much less than in the primary groups; soft as well as hard sandstone, clay as well as shale, soft as well as hard limestones, occur continually. And just as in the primary strata the induration and subcrystalline aspect of the rocks was at a maximum in the older systems, so in these the contrary characters, softness and earthiness of texture, become the most conspicuous in the upper or most recent groups.

Thus it is evident that the consolidation and molecular aggregations of the rock masses of similar chemical and mineral nature are dependent on general influences, such as pressure and heat, whose effect would naturally be greatest in the oldest rocks, because these have been not only exposed the *longest time* to their influences, but also submitted to the highest degrees of their action.

Succession of Secondary Strata.—Three characters are employed in establishing the classification of secondary strata; first, their mineral constitution; second, their respective conformity or unconformity; third, the nature of their organic contents; in many instances these coincide remarkably; where they differ the classification is embarrassed. All the classifications, however, are to be supposed only locally true; for it is already ascertained that none of even the larger assemblages of secondary strata are universal or even very general in their distribution, nor very uniform in any one of their characteristics, except for limited areas. The most convenient classification for the European basin is, however, found to be sufficiently applicable to all the Mediterranean and Transatlantic regions, part of Central Asia, and the basin of the Indus.

The British series of secondary strata is one of the most complete in Europe, and sufficiently developed, even in the parts where it yields to the German type (red sandstone system), to serve as a general basis of comparison. The following is a concise scheme of the arrangement usually adopted in Great Britain:—

Names of Formations.	Thickness.	Remarks.
	Feet.	
7. Cretaceous System,	1,000	Composed of soft white limestones and argillaceous and siliceous rocks, all conformable in stratification, and containing similar groups of organic remains.
6. Oolitic System,	3,000	A complex or polymeric series of calcareous, argillaceous, and arenaceous strata, associated in several rather similar groups of three terms each (limestone, sandstone, clay). The organic remains of the whole system somewhat similar, yet in fact differing in each group, and in each term of the groups.
5. New Red Sandstone, Saliferous or Poecilitic System,	1,200	Arenaceous, argillaceous, and calcareous strata, intimately associated in several repetitions. Red colour very predominant. Organic remains few and local.
4. Carboniferous System,	6,000 to 16,000	Calcareous, arenaceous, and argillaceous strata, with beds of coal and ironstone. The limestones usually low in the series, the coal most abundant above. Many land plants with the latter, the former with marine exuviae considerably <i>analogous</i> to those of the silurian system.

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4. CARBONIFEROUS SYSTEM.

Geographical Extent.—This valuable series of strata, to which Great Britain owes so much of her commercial prosperity, is extended irregularly over the basin of Europe, in North America, Australia, &c. It occupies large breadths in Scotland, Ireland, England and Wales, and lies in patches in various quarters of France, Germany, Poland, and Russia. Commonly it is found at the foot or on the flanks of primary mountains which had been previously uplifted, so that its stratification is not in accordance with theirs. In particular regions, however, there is no such break in the continuity of deposition, but, as in Herefordshire, the passage is gradual from the upper silurian sandstones and shales and limestones to the limestone, shales, and sandstone, and coal of the carboniferous systems. In such a district it might be quite reasonable (since the organic remains, though minutely different, are often generically similar) to unite the upper primary and lower secondary rocks; but this local practicability must yield to general convenience.

Succession and Thickness of the Strata.—The variations in the development of the carboniferous system are considerable, and its occurrence is often in detached portions: it is therefore requisite for obtaining a general section, to combine the results of different and independent observers. The most complete view of the lower part of the system is found on the border of Wales adjoining the silurian rocks. The middle and upper portions are most fully exhibited in the north of England. There are three great formations included in the carboniferous system.

Upper Formation, or Coal Measures; three thousand feet thick in the north of England, consisting of abundance of sandstone and shales, layers of ironstone, and beds of coal. Of these are many alternations, constituting a series of many nearly similar terms, usually containing at least the three substances,—coal, sandstone, and shale. Scarcely any limestone occurs in this upper coal-measure series. One bed is, however, found in the Yorkshire coal-field, containing *marine shells*, while in all the rest of the strata nothing but fresh-water and terrestrial exuviae occur. A limestone bed with estuary shells is found in Shropshire, and near Manchester.

The coal seams, twenty or thirty in number, amount in all to a thickness of about sixty feet, in a mass of shales and sandstones at least 3000 feet. Nearly the same thickness of coal occurs in the coal-fields of Newcastle, South Wales, &c. though the earthy substances enclosing the vegetable products vary in nature and thickness. The thickest coal-seams in Staffordshire and Ayrshire, ten or fifteen yards, are in fact composed of many beds of different qualities aggregated together. The quality of coal is partly dependent on the plants of which it was originally composed, and partly on subsequent changes produced by subterranean movements, effects of heat, &c. The principal differences arise from the variable quantity of gaseous matter. In the stone coal (blind coal or culm) of South Wales, Kilkenny, and Virginia, which burns like coke, there is little or nothing but carbon and earthy admixtures. The box or cannel coal of Lancashire and Yorkshire, which blazes like a candle, contains nearly half of its weight of gaseous matter. There is but little coal, and that in the lower part of the series, in Ireland.

The ironstones of a coal district lie generally in layers of nodules, each frequently enclosing a leaf or shell, or some other nucleus of molecular attraction.

The shales are bituminous or sandy; the sandstones laminated or massive, micaceous, argillaceous, subcalcareous, or felspathic, very rarely of a red colour, though blue, yel-

low, brown, white, and other tints prevail. Chalybeate springs are general, and salt springs not uncommon in the northern coal tracts.

The Mountain Limestone Formation is best examined in the north of England¹ in the region between Pendle Hill and the Tyne. The whole series undergoes great changes, so as to afford northern and southern types applicable to all parts of the mountain limestone formation yet known in Europe.

The Southern Type, complete in Derbyshire and the south of Yorkshire, is composed of three terms, viz.—

Upper Term.—Millstone grit, a coarse sandstone, in one, two, or three masses, with shales and bad coal.

Middle Term.—(Limestone shale), a thick mass of bituminous shale, in which locally black limestone bands and nodules of ironstone occur.

Lower Term.—Limestone of Derbyshire (Lower Scar limestone of Sedgwick and Phillips), a great mass of calcareous rocks almost entirely free from arenaceous and argillaceous admixture.

To this type all the south of England mountain limestones, as well as those of Ireland, Belgium, Dusseldorf, and Silesia are to be referred.

In the *Northern Type* the same three terms are compounded and otherwise varied.

The upper group is composed of three millstone grit rocks, alternating with shales, laminated sandstones, coal seams, ironstones, chert beds, and thin limestones.

The middle group consists of shales alternating with sandstones mostly laminated, ironstones, coal seams, chert beds, and five or more limestone rocks, each from ten to eighty feet thick. (The name of Yoredale rocks is given to this group in Yorkshire.)

The lower group consists of limestone, alternating with shales and some sandstones, coals, &c.

To this type belong all the Northumberland limestones, and those of the basins of the Forth and Clyde. The limestone of Burdiehouse, near Edinburgh, is maintained by Dr Hibbert to be of fresh-water origin.

The lower part of the group, round the Cumbrian mountains, and along the Penine escarpments, from Brough to Brampton, contains alternating red sandstone beds, thus constituting a real transition to the next or old red sandstone formation.

The old red sandstone formation varies in its character so as to offer little that is really of general application except its colour, and the absence of coal, and rarity of limestone. Along the flanks of the Grampian, Lammermuir, and Cumbrian mountains, it is chiefly a rude conglomerate of pebbles torn by violent floods from the neighbouring high ground; but on the borders of the Welsh slates it is a complicated mass of arenaceous, calcareous, and argillaceous strata, graduating to the upper silurian system. Mr Murchison has thus classed the beds 10,000 feet in thickness, which he ascribes to the old red sandstone of the Welsh border:—

Upper part.—Red quartzose conglomerate, overlying thick bedded sandstone. (Without organic remains.)

Middle part.—Red and green (mottled) concretionary limestones, with spotted argillaceous marls and beds of sandstone. (Singular fishes, Cephalaspis of Agassiz.)

Lower part.—Flaggy, highly micaceous, red and green sandstone. (With shells.)

In the *Geology of Yorkshire*, vol. ii. is the following conspectus of the whole carboniferous group:—

¹ See *Geology of Yorkshire*, vol. ii, and Sedgwick's *Memoirs in Geological Proceedings and Transactions*.

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	North of England and Scotland.	Derbyshire, North and South Wales.	Belgium and South of England.	Ireland.
COAL FORMATION	Coal, shale, grit, and ironstone	Coal, shale, grit, and ironstone	Coal, shale, grit, and ironstone	Coal, shale, grit, and ironstone.
Transition Series	Millstone grit, coal shale	Millstone grit, or farwell, rock shale	Millstone grit, or farwell rock, shale	Kulkeagh grit. Kulkeagh shale.
CARBONIFEROUS LIMESTONE FORMATION	Yoredale { Limestone, Gritstone, Shale, and Coal }	'Limestone shale'		Kulkeagh limestone. Loch Earn shales and grits.
Transition Series	Lower Scar limestone group	Mountain limestone	Limestone and shales	Enniskillen limestone.
OLD RED FORMATION	Alternations of red sandstone and limestone	Alternations of red sandstone and limestone	Alternations of red sandstone and limestone	Alternation of red sandstone and limestone.
	Red sandstones and red conglomerates	Red sandstone and conglomerates	Red conglomerates	Red sandstone and conglomerate.

STRATIFICATION.

This varied series of rocks shews, in all its parts, the clearest proof of successive deposition; laminæ, beds, strata, whole rocks, and groups of rocks, are here seen to be generally parallel. It is, however, very true, that in each kind of rock the phenomena indicative of successive deposition are so far different as to admit of definition. The argillaceous members are universally laminated, but it is rare to see the laminæ aggregated into beds. In a thickness of a few hundred feet, are many thousand laminæ, but *no real beds*; in a mass of limestone, forty to eighty feet, are *no laminæ*, but many beds; in micaceous sandstone, are both laminæ, and beds; and in some block sandstones are oblique laminæ and irregular oblique or waving beds. Does not this shew the imperfection of the nomenclature commonly used, which confounds all those various *structures of deposition* under one vague term of stratification? Yet, on the other hand, how full of instruction are those different phenomena: are we not clearly informed by them of the different conditions of the aggregation of the different chemical substances? Is it not apparent that the deposition of the argillaceous beds was subject to only minute and short interruptions; that the limestone rocks were formed at intervals; and the sandstones accumulated with much irregularity?

The deposition of limestone is of an oceanic character; its maximum thickness and purity is in one direction, while that of the arenaceous and argillaceous rocks lies in another, and marks the agitation of the sea along its ancient shores, where rivers and inundations brought sediments to be swept away by the tides and currents.

The organic remains of the carboniferous system are extremely numerous: upwards of four hundred species of animal exuvæ have been figured from the mountain limestone alone; probably 200 species of plants belong to the coal measures, and it is certain that in both these formations considerable additions will yet be made: a few remain to be added from the old sandstone. The following short summary of British species is all that our limits allow us to introduce:—

	Coal Measures.	Mountain Limestone.	Old Red Sandstone.
Plants—Marine . . .	1	...	...
Terrestrial . . .	150	...	...
Zoophyta—Polyparia . . .	...	41	...
Crinoidea . . .	...	40	...
Echinida . . .	...	3	...
Mollusca—Conchifera . . .	10	36	...
Plagimyona . . .	4	24	...
Mesomyona . . .	...	110	a few.
Brachiopoda . . .	1	95	...
Gasteropoda . . .	...	10	...
Cephalopoda Monoth . . .	3	78	...
Polythal . . .	...	10	a few.
Crustacea—Trilobites, &c. . .	10?	a few.	a few.
Fishes . . .			

The account of plants is derived from comparison of the works of Brongniart, Lindley, and Hutton, &c. and from private sources; the other parts are chiefly taken from the Geology of Yorkshire and Sowerby's Mineral Conchology.

SYMMETRICAL STRUCTURES.

The jointed structure of rocks of the carboniferous system has been minutely investigated. In the Geology of Yorkshire, vol. ii. it is shown, from eighty-five observations in the carboniferous system, that in the mountain limestone and coal tracts of Yorkshire, the *long joints* affect certain principal directions, so that two positive axes in which these divisional planes are most frequent, are traced at right angles to one another; and two negative axes in which *no* long joints have been observed, also at right angles to each other. The axes of frequent joints run N.N.W. and S.S.E., and E.N.E. and W.S.W.; the negative axes are N.E. by N., and N.W. by W. This singular result of observation harmonizes with the principal directions of mineral veins in the district bordering on the great Crossfell and Craven faults; it also bears a close analogy with the deductions from mechanical theory of Mr Hopkins, (Cambridge Trans. 1836), as to the production of planes of fissure at right angles to each other, in cases of continuous pressure being applied to large areas of the earth's lamellar crust.

The directions above named of the positive axes, obtain in newer strata (oolitic and red sandstone systems), and in situations at great distances from the Penine faults, and it appears probable that the joint planes are due to extremely general agency.

These researches should be followed up in other districts, and in other systems of strata. The following table is extracted from the work above named, and it refers to diagram, No. 12.

No. 12.

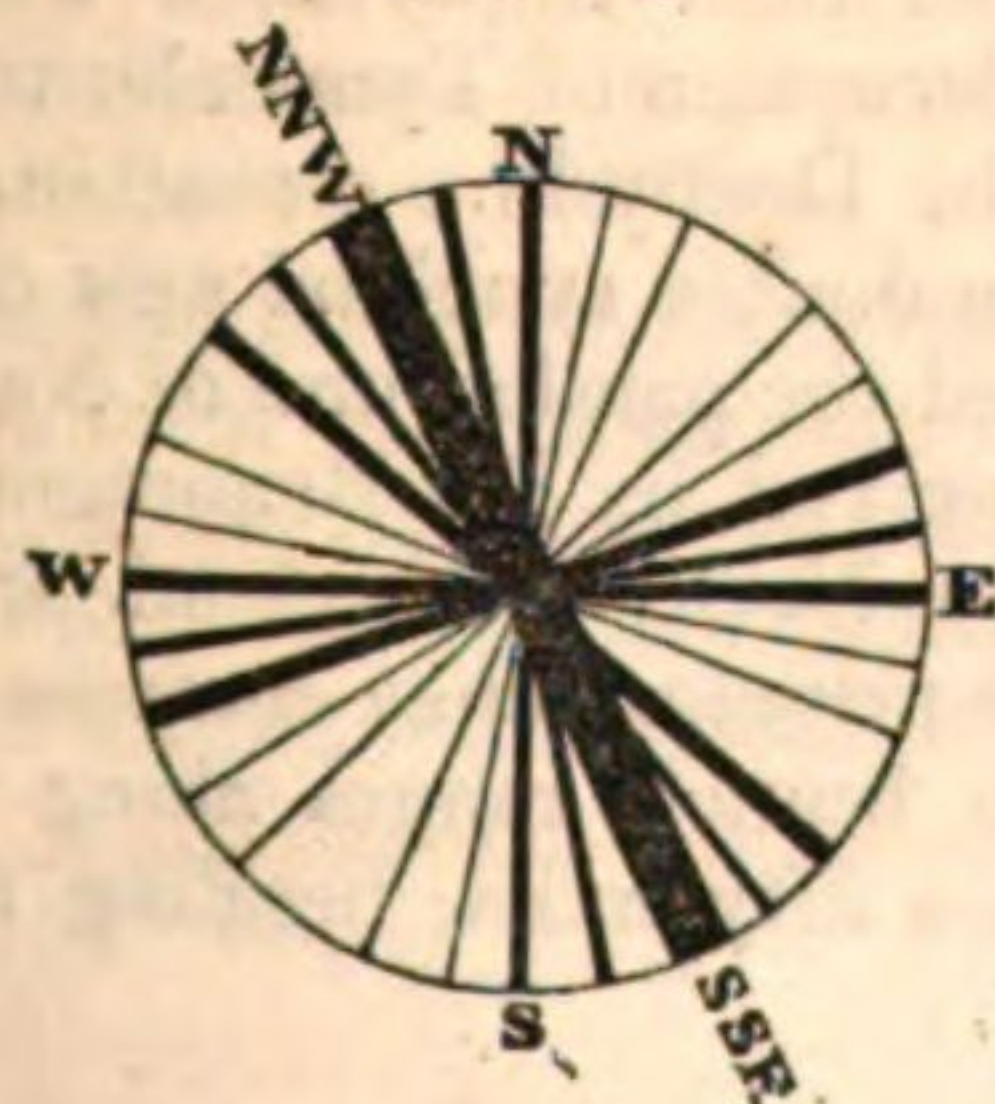


Table of the Directions of Long Joints in Yorkshire.

Names of Formations.	No. of Obs. in Yorkshire.	W. by N.	W.N.W.	N.W. by W.	N.W.	N.W. by N.	N.N.W.	N. by W.	N.	N. by E.	N.N.E.	N.E. by W.	N.E.	N.E. by E.	E.N.E.	E. by W.	E.
Magnesian Limestone	4	...	...	...	1	...	1	...	1	...	1	...	...	...	...	...	...
Coal	3	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...	...
Millstone Grit	13	...	...	...	...	1	5	2	...	...	...	...	...	...	4	1	...
Chert Group	17	...	...	...	1	4	6	...	...	...	...	...	1	...	4	1	...
Yoredale Series	35	...	2	...	1	1	8	5½	5½	...	...	...	2	1	3	2	4
Scar Limestone	15	1	...	...	4	1	2	1	2	...	...	...	...	1	1	...	2
Old Red Sandstone	1	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...
Whin Sill	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
	89	1	2	...	7	7	23	9½	9½	1	1	...	3	2	12	4	7

Igneous rocks are of frequent occurrence in the carboniferous system of the British islands, especially in the northern parts of England and southern parts of Scotland. It is very deserving of attention, that they are principally of the augitic and hornblendic family of igneous rocks. Greenstones and basalts are the prevalent rocks which lie in interposed beds, or fissures in the stratified limestones, shales, and limestones.

While among the slates of Cumberland and the Lamermuir porphyritic rocks of many kinds abound, the coal-measures and limestone rocks, not far removed, have only basaltic or greenstone masses mixed with them.

The porphyry of the Cheviot and some other points along the Tweed, may indeed be ranked as exceptions. In Northumberland, Cumberland, and the northern part of Yorkshire, a stratiform mass of greenstone and basalt (whin sill) is interposed in the midst of the limestone series, apparently originating in several submarine lava currents. In Derbyshire, a somewhat analogous rock ("toadstone") interlaminates the limestone; in the Clee Hill, a mass of basalt ("jewstone") has overflowed the coal. More commonly, through all the coal-field of Durham and Newcastle, and not unfrequently in the coal-basins of Scotland, rocks of the same kind have been injected in the fluid state into open fissures of the sandstones and shales, constituting whin-dykes. At the point of contact of these crystallized rocks with the coal, the latter is converted to coke (North of England), or to anthracite (Old Cumnock); earthy limestone is converted to crystalline (Teesdale); shale and sandstone are hardened to jasper (Salisbury Crags, &c.); garnets are generated in the shales of Teesdale. It is worthy of remark, that the 'whin-dykes' of the North of England are often *unaccompanied by dislocation*.

Mineral veins abound in particular parts of the carboniferous rocks, chiefly in the limestone districts, and near to some considerable dislocations or axes of distinct elevation. Scarcely a single mine in the British islands is worked in the old red sandstone, or true coal-measures; very few are established in districts which, like a large part of the Irish limestone, are removed from axes and centres of disturbance. But the dislocated mountain limestone of Cumberland, Durham, Yorkshire, Derbyshire, Flintshire, Mendip, and South Wales, and partially that of Belgium and Silesia, is characterized by prevalence of veins of lead, copper, calamine, and oxide of iron. There is seldom found in these districts the same great variety of metallic ores as in the older primary tracts; the vein stuff (matrix of the ore) differs according to locality—fluor-spar abounds in the mines of Aldstone Moor, &c.—carbonate of barytes in Derbyshire. It is seldom that the same mining districts, almost never the same veins, yield copper and lead in abundance. One might venture to say, there is a peculiar elective attraction between sulphuret of lead and limestone rock; and this idea, followed too far, leads to the doctrine

of the metallic contents being secreted from the bordering rocks. The materials of the veins seem indeed in many instances to have been transferred by (electric) currents through solid substances, but they are really diffused *from* the veins into cavities of the neighbouring rocks, not collected from these *into* the vein fissures.

Most of the veins of fissure are accompanied by dislocations ("faults"), sometimes to the extent of several hundred feet, sometimes only a few inches. They pass through the stratiform basalt of Northumberland and Yorkshire, and *yield ore in it abundantly*; but though the toadstone of Derbyshire does not, as was once imagined, "cut the veins off," they are only feebly traced through it. But this circumstance is not peculiar to the igneous rocks; often, and perhaps generally, the veins in a limestone district are greatly contracted ("nipped") and unproductive at the places where they divide the shales, and grow wider and more prolific in the limestones and thick gritstones. Pipe veins are of less frequent occurrence and inferior interest. Ecton is one of the most remarkable of these.

The same phenomena of some veins crossing and cutting through others occur in this district as in the older strata, and the same tendencies to peculiar directions are recognised; the bearing veins running generally east north-east, or nearly so, and the cross courses north by west, in the north of England and Flintshire.

DISTURBANCES OF THE CARBONIFEROUS SYSTEM.

After the deposition of this system, and before at least any considerable proportion of the superjacent rocks was formed, very extensive displacement happened in most parts of the surface of the globe where the carboniferous rocks had been deposited. Not that such displacements were limited in geographical extent to the area of this system; on the contrary, from there hardly being a known coal tract exempt from this influence, it would appear that convulsive movements took place of a very general description, so as to affect very large tracts of the surface of the globe. In the British islands, every coal district is disturbed and shaken in every square mile of its breadth by faults ("gauls, slips, troubles, and dykes"), passing in many directions, some of them having a great amount of "throw," and consequently affecting the working of the mines. But these minor effects, though on some accounts very interesting, lose their importance when we contemplate the gigantic disruption of Tynedale, the Penine chain, the Craven fault, the Derbyshire elevation, the fault of the vale of Clwydd, the double synclinal axis of the coal-fields of South Wales, and the parallel one of Namur. The Penine disruptions, ranked by De Beaumont under the title of the System of the North of England, are on a magnificent scale. Three principal lines compose this great system—the northern branch ranges along Tynedale from Brampton to the sea fifty miles, bending more than once

Geology. from its average recticlinal course to the east by north; the southern branch passes in a straight line to the east-south-east thirty miles, and the two are connected by a line of fault, whose mean direction is nearly north and south, but it has three several courses in a length of fifty miles. The Craven, or southern branch of the system, is a double fault; the Penine line is partly an anticlinal and partly a fault; the Tynedale branch is one great fault. With reference to a point in the middle of the area, enclosed by their dislocation, their effect is everywhere similar, viz. a mighty depression of all the exterior country. North of the Tynedale fault, is a depression or throw of 1000 to 2000 feet; west of the Penine fault, 2000 or 3000, or perhaps 4000 feet under Crossfell; and south of the Craven fault 3000 feet at least under Ingleborough.

There is no direct connexion between this great Penine system of faults, and the elevation of Derbyshire; between them is a singular system of anticlinal elevations and synclinal depressions, all chiefly ranging north-east, or north-east by east, from the Craven fault, right toward the more ancient but parallel anticlinals of South Wales. Before, however, reaching these lofty chains, a transverse break, almost exactly similar to the Crossfell fault, ranging north north-west, along the vale of Clwydd (which is a miniature copy of the vale of Eden), stops the Ribblesdale system of anticlinals in the south-west, just as the Craven fault, ranging west north-west, has stopped them on the north-east. It is from nearly the middle of the Ribblesdale faults that an anticlinal ridge, ranging south south-east, passes along the western border of Yorkshire and continues into Derbyshire, on the southern side of which county it is apparently cut off by an east and west fault.

Charnwood Forest is an elevation of slate rocks (on an axis of sienitic rocks), and the date of its elevation is posterior to the limestone and coal-field of Ashby, but anterior to the new red sandstone system, which is seen to lie level over its vertical and broken slates. The other central coal-fields of Warwickshire, Staffordshire, and Shropshire, were dislocated at about the same or perhaps somewhat later period, for the magnesian conglomerate is disturbed by the faults of the Coalbrookdale-field. From this field to the Malvern Hills, a great north and south axis of violent elevation occurs, which in places actually overthrows the strata (Murchison in Geol. Soc. Abstracts), and others proceed south-west, parallel to Wenlock Edge, till they reach the vale of the Towey.

Here a new axis of dislocation becomes predominant, that of the South Wales coal-field, which runs east and west from St David's in Pembrokeshire, through the counties of Caermarthen, Glamorgan, and Monmouth, and may be considered to continue into the Mendip Hills and Somersetshire. Parallel to this, and in fact in the line of its prolongation to the east, is the coeval disturbance of the coal from near Boulogne through Belgium and Westphalia, and in the south of Ireland. A parallel but perhaps earlier disturbance ranges along the northern boundary of the greywacke region.

It would be impossible here to investigate all the bearings of the mass of evidence furnished by these variously directed dislocations, on the dynamical principles of geology, but they are too important to be overlooked. We may, however, observe, that dislocations of different dates are thus shewn to be parallel, while others presumed to be coeval range in different directions.

STATE OF THE GLOBE DURING THE CARBONIFEROUS PERIOD.

Recollecting the proof already given of the partial elevation of our present dry land, we shall be prepared for considering the nature of the new conditions introduced into the geological formula, by this circumstance, and the variation of surface temperature, already concluded to be admis-

sible as a geological cause. The Grampians and other mountain chains being raised above the sea, and shore and deep sea currents established, we shall not be surprised to find the traces of mechanical movement in the ocean suddenly grow very strong and extensive. We find, in fact, round all the mountain ranges, which for other reasons were presumed to have been uplifted before the carboniferous epoch began, some of the most remarkable conglomerate rocks which occur in the British strata. The character of these conglomerates, too, varies in direct relation to the proximity of the mountains. The composition of the red conglomerates of the Grampian borders reminds us continually of the rocks of the Highlands; those which surround the Lammermuir Hills are full of pebbles derived from these mountains (Boué); those which border the Cumbrian group contain pebbles of the neighbouring rocks.

What is the cause of the universal red colour of these ancient sediments, is already felt to be an important problem, for it appears connected with absence of organic exuviae in more than one instance. Shall we say that the local accumulation of the old red conglomerates was a consequence of the local elevation of the primary strata from the bed of the sea?

During the course of the carboniferous period the sediments of the sea underwent a total change, for red sandstones and clays are scarcely seen (except locally) among the coal-measures, or in the upper parts of the mountain-limestone series. Shall we say that the dark shales and variously coloured grits came from regions in different directions? The great quantities of those sediments imply, probably, some great physical changes of land and water in situations not far removed. The alternation of these deposits marks periods of intermitting action, and the circumstance of the prevalent association of terrestrial exuviae in these, but not in other strata, seems to instruct us that the earthy and vegetable materials were swept down from the land by some such means as a great river or periodical inundation. If so, the origin of coal and that of the accompanying characteristic rocks (or "coal-measures") is understood, the regular thickness and extension of the strata of coal are ascribable to the watery agitation, which at once permitted the association of similar earthy particles into shale and sandstone respectively, and collected the vegetable masses into layers. De Luc's notion of the origin of coal from submerged peat beds is too limited and encumbered with inextricable difficulties to be ever adopted as a general doctrine, nor can the minor analogies observed between the position of the subterranean mass of vegetables, the vertical trees, and (often imaginary) roots and branches, be held at all conclusive. What can be thought of an hypothesis such as that just named; when we try to apply it to a case like a north of England coal-field, with its numerous parallel seams of coal, ironstone, &c. for every one of which seams the land must first have been dried and covered with soil, then submerged to receive oceanic sediments; no fault, no want of conformity in the stratification, no unusual violence of water being in any case observable to justify the hypothesis of rising and falling land? Again, will it be supported for a moment in a country where limestone, shale, gritstone, coal, are repeated many times (as in the dales of the north of England); yet where the grits and shales vanish, every trace of coal also disappears? If there be any truth in the hypothesis, coal should be found in the midst of the limestone as well as enclosed in gritstone or shale; some independent proof should be given of the rising and sinking being limited to certain tracts; or some reason assigned for the dependence of coal on the occurrence of such sedimentary rocks.

It is evident that the general arguments must prevail, and the condition of the plants which compose the coal, the general absence of roots, the fragmentary state of the stems and branches, the dispersed condition of the separa-

Geology. ble organs, the splitting and reunion of coal beds, all the phenomena, in fact, really general, confirm the conclusion that the plants whereof coal consists were swept down from the land on which they grew by watery currents, often repeated, and deposited in basins or large estuaries of the sea, or, perhaps rarely, in lakes of fresh water. The alternation of a bed of marine limestone in the Yorkshire coal-field, and perhaps the broad layers of bivalve shells (*Unio*), which appear sometimes in positions indicating that they lived and died where they are now found, shew an estuary deposit liable to temporary predominance of salt water. In the coal-fields of Shropshire and Manchester, the supposed fresh-water limestone may perhaps be ascribed to the influx of a river, and other coal deposits probably have happened in the deep sea at intervals during the accumulation of limestone.

What, then, were the circumstances of the dry land favourable to the growth of the enormous mass of vegetable substance which is buried in the coal formation? That the atmosphere was warmer, and, by consequence, moister, may be easily admitted, and in fact what is known of the structure of the plants goes to confirm this opinion; for the most abundant forms are at least analogous to tropical vegetation. But in addition, it has been conjectured that the atmosphere might in those early periods have an unusual dose of carbonic acid gas, and thus be more fit to supply the carbon requisite for the growth of such vast forests as then must have encumbered the limited surface of the land. This speculation of Brongniart appears worthy of attention; nothing known to the chemist or natural philosopher is opposed to the notion that the quantity of carbonic acid gas in the atmosphere may be extremely variable; it would not indeed be favourable to the life of animals, but *what proof have we of the globe being then tenanted by terrestrial animals?* Moreover, speculation apart, let any one calculate the quantity of carbon contained in a single English coal-field, once a part of the living structure of plants, and add the equivalent volume of carbonic acid gas to that small quantity which it now holds, the consequence will be an atmosphere charged with this pabulum of vegetable life, to a degree perhaps very favourable to the growth of plants, but certainly detrimental to the life of animals breathing by lungs. Now, surely, it is worthy of attention, that *after the coal was deposited*, reptile life began to be manifested, and finally, to predominate; while, on the other hand, vegetable life, though the land was much more extensive and apparently not much lowered in temperature, never yielded again such thick and extensive carbonaceous deposits.

From the nature of its numerous organic contents, as well as from the texture and composition of its masses, there is no doubt of the mountain limestone being truly an oceanic deposit, diminishing and growing debased toward the shores, but accumulating in masses of greater purity toward the deeper seas. It appears to have been a chemical precipitate, more or less tranquilly produced; and if we may venture here to combine the facts known concerning the primary and secondary limestone, it will appear the most probable inference, that a slow decomposition of the oceanic waters, partly by organic, partly by chemical action, is the true cause of the production of marine limestone.

NEW RED SANDSTONE SYSTEM.

Geographical Extent.—The irregular expanse of sea left in the region of Europe by the broken masses of land, belonging to the uplifted carboniferous rocks, was perhaps not fully filled by the next succeeding deposit of sandstones, clays, and limestone, which receives the name of Red Sandstone, or Saliferous or Pœcilitic formation, but it is very extensively diffused in and beyond this area. It occurs in Ireland, but not abundantly, and only in the north eastern part, which may be viewed as a dismemberment from the Lam-

mermuir district of Scotland. In Arran, and on the west coast of Ayrshire, on the south side of the Lammermuirs, round Dumfries and Longtown, is a large tract of these rocks, spreading into the plain of Carlisle, the vale of Eden, and against the west face of the Cumbrian mountain limestone. Small detached parts occur farther south on the same side of the Lake district, and still smaller on the east, about Kirby Lonsdale.

But the greatest expansion of these rocks in England begins in Durham, about the mouth of the Tees, spreads southward in a narrow tract along the vale of York to Nottingham; then opens at once into the wide central plain of England, and occupies the whole breadth from the carboniferous tract of Lancashire, North Staffordshire, Derbyshire and Nottinghamshire, to Shrewsbury and Worcester, to Leicester and Shipston; then following the Severn to Bristol, it turns to the west along the south face of the South Wales coal-field, and is, interruptedly, continued south from the Bath Avon to the mouth of the Exe.

On the continent of Europe it occupies some space on the left bank of the Rhine in the district south of the Ardennes, and parallel to the Vosges; but on the right bank it is expanded over larger breadths in Wurtemberg, and occupies a great part of that enormous area included between Basle, Amberg, Leipzig, and Minden.

Almost universally it fills a low or level country, out of which arise insulated groups and short ranges of mountains of older strata or pyrogenous rocks. Such are Charnwood Forest, and the central coal-fields of England; the Vosges, Schwarzwald, Thuringerwald, Odenwald, Harz, &c., in Germany. Its highest point in England does not much exceed 800 feet above the sea.

Succession of Strata.—This system consists of many alternations of arenaceous and argillaceous members, with some less continuous interpositions of limestone, usually impregnated with magnesia. The best types of the system are those of Germany, the south-east of France, and north of England. The most complete in all respects is that of Germany; but it will be convenient to describe the English series, and afterwards to present a general conspectus of the whole. It is to Professor Sedgwick (on Magnesian Limestone, Geol. Trans.) that we owe the most successful classification for England; and the labours of Voltz, Elie de Beaumont, &c., have ascertained all that is required for drawing the lines of geological contemporaneity between England and Germany.

Upper red sandstone formation.—Consisting of variegated red, white, and other clays, with gypsum; (organic remains, few and local). Red and white sandstone, with or without layers of clay; (few or no organic remains). Red conglomerate of pebbles derived from older rocks, imbedded in red sandstone; (no organic remains).

Magnesian limestone formation.—Consisting of upper laminated compact limestone of a light or dark grey or smoky colour. A few organic remains.

Gypseous red and coloured marls.

Lower or magnesian limestone, of a yellow colour, earthy, granular, crystalline, or concretionary in texture, and (locally) organic remains in considerable abundance.

Marl slate or calcareous laminated rock, yielding fishes of the genus *Palæoniscus* chiefly.

Lower red sandstone formation.—Red and yellow sandstones with (locally) red and coloured clays, and plants like those found in the coal series.

The usual arrangement adopted in England unites the lower red sandstone, with the magnesian limestone formation. It is of little importance, however, whether we conceive the whole system to be but one formation, or divide it into two or three. On the western side of the north of England (Plain of Carlisle), the upper red sandstone retains its usual character; the magnesian limestone is re-

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presented by a calcareous conglomerate. Further south near Manchester, red and greenish marls and concretionary limestones, both fossiliferous, divide the upper from the lower red sandstones. In the centre of England (Cheshire, Worcestershire) salt rocks and springs occur. In all the southern districts (Shropshire, Gloucestershire, Somersetshire), a calcareous conglomerate represents the magnesian limestone, and the lower red sandstone is only locally seen. In the district south of the Ardennes, and along the Vosges, there is no magnesian limestones, but in the midst of the variegated marls, lies a thick limestone rock (muschelkalk), in some respects comparable to the upper laminated limestone of the north of England, but containing many and different organic remains. In the variegated clays above the muschelkalk, is a thin bed of magnesian limestone; with this series of variegated clays is associated a variety of sandstones locally rich in plants, the whole group being in France called "marnes irisées," in Germany, 'keuper'. The red grit of the Vosges (Grès Vosgien, Volz) is rather a local rock peculiar to that district, than a part of the lower red sandstone, which does, however, occur there beneath it. But in the Thuringerwald and north east of Germany, in addition to these, we have limestones corresponding to the upper and lower magnesian limestone, gypseous marl, and marl-slates of England, under the general name of Zechstein. Thus the whole is capable of being represented in one formula, which is well calculated to shew both the agreements and differences usually observed in comparing distant parts of a stratified formation.

North-east of Germany.	The Vosges.	South of England.	North of England.
Keuper sandstones and marls.	Marnes irisées.	Variegated marls.	Variegated marls.
Muschelkalk.	Muschelkalk.		
Bunter sandstone.	Gres bigarré.	Red and white sandstone, conglomerate.	Red and white sandstone and conglomerate.
Zechstein.		Calcareous conglomerate.	Magnesian limestone.
Rothetodteliegende.	Gres Vosgien gres.		Lower red sandstone.

Salt is associated with the upper parts of this system in England, France, and Germany, where the muschelkalk is quite as saliferous as the variegated marls, to which apparently salt is confined in England. Upon the whole, then, this red sandstone system is a vast mass of sandy and argillaceous sediments of a peculiar aspect, accompanied more than any others yet known by salt and gypsum,—generally deficient in organic remains, and only locally inclosing strata of limestone, which commonly are characterised by abundance of magnesia.

In the north of Germany the lower beds of it seem decidedly related to the coal deposits, (as also happens in the north of England); in fact, the coal is supposed by Hoffman to be only a local product in a vast mass of red rocks, including the whole series of the old red and new red rocks. Nearly the same thing takes place in Arran where the diminished carboniferous system is merely a parting in the enormous thickness of red clays, sandstones, and conglomerates. Thus, it is evident that our best classifications of the series of stratified deposits can only be locally exact, and authors of such arrangements must be prepared to see them rejected, as in many cases inapplicable or very inconvenient.

Stratification.—The same laws of phenomena on this subject obtain in the red sandstone as in the carboniferous system; the argillaceous masses are laminated, often composed of alternating white, greenish, and red layers; the sandstones when very fine are also, in general, thinly bedded; where very coarse they are in ruder and less regular

layers; where pebbles and sand are mixed (Nottingham Castle), the layers are oblique in various directions, like the heaps of detritus left by rapid rivers or other sudden violence of water. The limestone beds, if argillaceous, are thinly bedded; if magnesian, they are often thicker, less regular, full of sparry geodes, and strings and veins of carbonate of lime. These magnesian rocks are also often very concretionary, sometimes oolitic, in particular parts (Mansfield, Nottinghamshire) composed of real crystals of the double carbonate of lime and magnesia. Some beds have a conglomerate character, and in such, generally, stratification is almost imaginary, and the joints which pass through the other beds, lose themselves without penetrating this. (Shields and Sunderland.)

Organic Remains. South of a line drawn through Chester and Derby, organic exuviae of plants or animals have been rarely found in the red sandstone system of England; none have yet occurred in that of Scotland; but fishes have been discovered in that of Ireland. (Report of Proceedings of British Association at Dublin, 1835.)

In the space north of this line it is only on the western side of the island that a marine plant has been found in red sandstone, at Runcorn near Liverpool (Dr Buckland, 1834), marine shells (conchifera and gasteropoda) lie in the red and white marl, and calcareous bands near Manchester. On the eastern side of the island the lower magnesian limestone is nowhere entirely destitute of shells and zoophytes, which have often a great analogy to those of the carboniferous rocks: the upper laminated rock has also a few shells, the lower red sandstone many plants.

In Germany, the rothliegende, zechstein, bunter sandstein, muschelkalk, and keuper, all contain organic remains, and locally even in considerable quantity.

No complete list of the fossils of the English magnesian limestone has ever been published. Professor Sedgwick, however, (Geol. Trans.), mentions a considerable number of the Durham fossils, and M. Agassiz has recently added to the list of fishes. The following summary includes some nondescript species now in the cabinet of the writer.

Plants	Voltzia?	
Zoophyta, .	Polyparia,	3
	Crinoidea,	1
Conchifera, .	Plagimyona,	9
	Mesomyona,	6
	Brachiopoda,	15
Gasteropoda,		4
Cephalopoda,		2
Fishes,		10?
Reptiles,		2 or 3

Igneous Rocks.—Basaltic dikes divide the magnesian limestone of the north of England; and in the Island of Arran (Jameson, MacCulloch, &c.) these and other dikes of pyrogenous rocks and interposed beds are extremely abundant in Corygills, at Tormore, and other points. Nothing of the kind is found in the greater part of the English red marl and sandstone; but the analogous red conglomerates and porphyritic masses of Exeter (investigated by De la Beche), appear important, as throwing light on the analogous, if not strictly coeval, mixtures of porphyritic and arenaceous rocks common in the north of Germany.

It is chiefly by the occurrence of porphyritic fragments and pebbles that the mixture alluded to takes place near Exeter; it appears a natural supposition that, in the confined accumulation of the red conglomerate from the action of violent water-currents, consequent on local displacements of the crust of the globe which followed the deposition of the coal-measures, some of the broken masses of igneous rocks should be retained among the materials then aggregated. In fact, the country was dislocated near the conglomerate of Exeter; and Mr de la Beche notices circumstances tending

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to shew that the porphyritic eruptions did happen, and sometimes overflowed parts of the conglomerate while it was in process of accumulation.¹

On the east side of the Harz the red sandstones and marls (of the Rotheliegende) rest on a porphyritic conglomerate, of which the porphyritic fragments are not always similar to the nearest quartz porphyry of Saal, often being larger in proportion to the distance therefrom. This conglomerate is regular and widely expanded, and none of the other beds of the red formation contain such porphyry pebbles. (Von Dechen).

Thus, it appears certain that the detritus of igneous rocks (generated, it appears, in Devonshire at the same era) furnished the materials of the lower beds of the Rotheliegende; and we may perhaps hereafter be able to form a conception as to the extent to which igneous eruptions, and wasted igneous rocks, may have modified the characters of the deposition of the whole system, which, in mineral, structural, and organic characters, offers much that is worthy of notice, and very alluring to imprudent theorists.

Metallic veins are, in England, very rarely heard of in the rocks, nowhere worked. Lead veins occur in the marl-slate near North Shields,—in the magnesian-limestone at Nosterfield, and Warmsworth, Yorkshire, and Barlborough Derbyshire; carbonate of copper is found at Farnhill near Knaresborough, Newton Kyme near Tadcaster, and Warmsworth; cobalt is found in Alderley Edge, Cheshire.

In Germany the slate-beds, which are the equivalent of the marl-slate, are loaded with copper about the Harz Mountains, and contain fishes. They receive the name of kupferschiefer.

DISTURBANCES OF THE RED SANDSTONE SYSTEM.

The most remarkable example is on the eastern face of the Vosges Mountains, where the upper beds of the system lie at the foot of great precipices of the Gres Vosgien. In England almost nothing of this kind is observable. The magnesian limestone is divided and dislocated by some of the faults and basaltic dykes which traverse the coal of the Newcastle district. One of the anticlinal lines west of Shrewsbury, which ranges from west south-west to east north-east, through the Breiddin Hills, has been noticed by Mr Murchison as continuing in a narrow course through the red sandstone of the plain of Shrewsbury, and directing itself toward the elevated coal and gritstone hills near Cheadle. The red sandstone along this line (at points fifteen or thirty miles from the Breiddin), is thrown into angular positions, altered and impregnated with metallic substances; and dykes of trap occur at Acton Reynolds. The most curious inference on the subject is, that the same line has been the locus of the igneous eruption and disturbing movement during the silurian, carboniferous, and red sandstone eras, a conclusion singularly at variance with the literal statement of De Beaumont's hypothesis, though, as being a solitary instance, it ought not to be too much insisted on. It appears from the same author and Mr Prestwich, that some of the most considerable dislocations of the border of the coal-fields of Coalbrookdale and Dudley happened after the deposition of a part of the new red sandstone; but it is certain that those of Somersetshire and Gloucestershire were completed before the date of that rock.

STATE OF THE GLOBE DURING THE FORMATION OF THE NEW RED SANDSTONES.

The greater extent of land, as indicated by the uplifting of many portions of the coal deposit, might have been ex-

pected to have caused greater local varieties in the composition of this system than we find. In fact, as a general rule, the traces of terrestrial admixture in the red sandstone deposits are remarkable, and unusually few. The shells and other organic exuviae are marine; and it is only in a few places round particular mountain ranges (the Black Forest especially), that the remains of land plants and reptiles are at all prevalent. Several reasons might be adduced to justify an opinion, that the time occupied in the production of the whole system was comparatively short,—such as the general uniformity of its composition, the deficiency (except in limited regions) of limestones; the peculiar chemical and mineral character of these limestones; the general paucity of organic remains; the frequency of conglomerates and local admixture of fragments of igneous rocks,—all these circumstances seem to indicate the predominance of an unusual series of agencies.

A notion has gradually been spreading, though it has perhaps not been distinctly announced, that many of these circumstances are the result of temporary volcanic excitement consequent upon the deposition of the coal-measures; but it is difficult to collect adequate reasons from the vague data at present known, for clothing this suggestion with the substantial character of a probable inference.

Concerning climate and other circumstances, the evidence from remains is of little value further than their analogy with those of the carboniferous system leads to the impression that no remarkable changes had occurred in this respect.

OOLITIC SYSTEM.

Geographical Extent.—In the British islands, and, we may add, in the continent of Europe, this mass of calcareous rocks is very unequally distributed, yet in particular regions its course is very persistent, and the different formations which compose it follow one another with remarkable conformity. Scarcely any traces of it occur in Ireland, except in the north-eastern part, which contains the chalk and red sandstone. It is found on the east coast of Scotland at only a few points about the Moray Frith, and along the Sutherland coast. On the western coast it occurs at Applecross, opposite to the Isle of Skye, and at several points in that island, and some of the smaller islets adjacent. In the same manner, it borders Mull, and is found skirting the mainland along the Sound of Mull.

But in none of the Irish or Scottish localities is the system completely, or even characteristically, exhibited; it is, in fact, more properly an English than a British system of strata, and there are few tracts of Europe where it is more expanded or so fully and variously developed. From the prominent parts of the Yorkshire coast, between Redcar and Filey, it holds an uninterrupted course, with varying breadth, through Yorkshire, Lincolnshire, Northamptonshire, Oxfordshire, Gloucestershire, Somersetshire, and Dorsetshire, to the southern coast between Exmouth and the Isle of Purbeck, almost everywhere forming a rather high table-land and dry surface, sloping regularly to the east, and dividing the eastern and western drainage of the island. It is nowhere narrower than in a part of Yorkshire near Bishop Wilton, where, in consequence of unconformity of the chalk, only the lower part of the lowest member is seen, and its breadth is only a few yards.

On the contrary, in the middle of the island, as in the counties of Northampton, Rutland, Gloucester, and Worcester, its breadth is even as much as forty miles. Toward the western edge, which is generally a line of bold escarpment, many outliers, or detached masses, occur, separated by watery violence or other causes. Of these the most

¹ *Proceedings of Geological Society*, 1834.

Geology. singular and far removed is the newly discovered basin of lias (the lowest of the oolitic formations) in the centre of the red marls and sandstones of Cheshire.—(Geol. Proceedings, 1835). Other extensive outliers follow the southern border of the South Wales' coal-field far into Glamorganshire.

On the continent of Europe the oolitic system is largely expanded; in France in a large semicircle round Paris, from the Ardennes to Normandy. It has a long range in Wurtemberg and Franconia; occurs in places along the range of the Carpathians (Poland), and margins, with a broad band, the north and south slopes of the Alps. It is supposed to enter into the composition of the Apennines, and the Dalmatian ridges, and to form a part of the limestone ranges of Spain, perhaps also of Greece.

The skirts of the Himalaya certainly contain at least its lower members, and perhaps these are not wholly unknown in North America.

Succession of Deposits.—There are three principal types of the oolitic system in which its developed characters appear considerably unlike; and it seems possible to ascertain the proximate influences or causes of the diversity. The series of oolitic rocks near Bath was the first field of the successful researches of Mr Smith in analyzing the secondary strata and determining the relation of organic forms to the successive stages of geological time. The excellent and exact arrangement which he here disclosed is the true fundamental standard of comparison for all the localities, not so much on the account of its being chosen by Mr Smith, as because it is in fact the most complicated (that is most fully expanded or developed) series of this system yet known. The following classification will be found very convenient for the Bath district.

Names and Description of Formations.	Constituent Groups.
Wealden Formation: a mass of sandstones and clays of various descriptions, iron, calcareous, carbonaceous; with layers and nodules of limestone, generally bearing the aspect of a fresh-water or estuary deposit.	x. The Weald clay. w. The Hastings sand. v. The Purbeck beds.
Upper Oolitic Formation: here imperfectly seen; composed of oolitic and other limestones, green and iron sands, and blue clays of considerable thickness, with organic remains. Composed of . . .	u. Limestone of Swindon, the Vale of Wardour. t. Sands of Swindon, and s. Clay of the Vale of North Wilts.
Middle Oolitic Formation: consisting of coralline and shelly oolites, calcareous sandstones and clays, with organic remains, . . .	r. Thin calcareous grit. q. Coral rag and oolite. p. Calcareous grit. o. Blue clay and septaria. n. Kelloway sandstone. m. Blue clay.
Lower Oolitic Formation: a complicated group of oolitic and shelly and sandy limestones, laminated and concretionary sandstones, sandy and tenacious clay, fullers' earth, &c. . . .	l. Cornbrash limestone. k. Forest marble group. i. Bath oolite. h. Fullers' earth rocks. g. Superior oolite, and f. Sandstone.
Lias Formation: chiefly argillaceous, with strata of limestone, all more or less argillaceous, but rarely oolitic; layers of sandy iron rocks, and septaria; abundance of organic remains, . . .	e. Thin upper lias clay. d. Marlstone rocks. c. Middle lias clay. b. Lias limestones. a. Lower lias clays, generally passing to new red marls.

Upon further examination in the country south of London, it is found that a superior formation, the Wealden

rocks, exists very extensively in Kent and Sussex, and this, for the sake of making the Bath series general for the south of England, has been placed in the above scheme of five oolitic formations.

In this alternation of limestones, sandstones, and clays, we behold deposits effected in periods of alternating disturbance and quiet, such as might happen not far from the shores of the ancient sea; and in the uppermost formation, the effects of agitated water predominate.

The next type, taken from Yorkshire, shews these littoral effects carried to extreme, in some parts of the sea, *but not in others*. The following is a short view.

The Wealden Formation. Unknown in the North of England.

The Upper Oolitic Formation, represented only by . . . } s. Thick clay.

The Coralline Formation is composed nearly as in the south of England, . . . } Upper group, { r. Upper calcareous grit.
q. Coralline oolite.
p. Lower calcareous grit.
Lower group, { o. Oxford clay.
n. Kelloway sandstone.
m. Thin blue clay.

The Lower Oolitic Formation is very different from that of Bath in detail, . . .

l. Cornbrash limestone, thin.
k? Sandstones and clays, with land plants, thin coal, &c.; calcareous sandstone, or sandy, concretionary, shelly limestone.
i? Oolitic limestone, thin.
h? Thick mass of sandstone (often carbonaceous) and clays, often full of plants, with coal-beds and ironstone.
g Irony and sandy limestone.
f. Sand, and concretionary limestone.

The Lias Formation is very similar to that of the south of England, and by adding the lower members from the Lincolnshire section, the whole is a more fully expanded series than that near Bath.

e. Upper lias shale (alum shale).
d. Marlstone, sandy and calcareous layers.
c. Middle lias shale (lower shale of Yorkshire coast).
b. Lias limestones of South Yorkshire and Lincolnshire.
a. Lower lias clays of the Trent-side (graduating to the red marls below.)

The oolitic series of Sutherland and the Western Isles of Scotland, investigated by Murchison, agrees nearly with the Yorkshire type: so does that of the whole northern line of Westphalian oolites, from Bramsche, by Minden, to Wolfenbüttel and Helmstadt, but the greater part of the continental oolites form a series analogous to that of the south of England. In Normandy there are almost exactly the same groups (M. de Caumont). On the south of the Ardennes (M. Boblaye), the clays of the English series grow less conspicuous, but the *series* is similar. In Burgundy (M. de Beaumont), the calcareous character of the group augments, and the argillaceous members diminish, so that the several oolitic formations become more difficult to define than in England. The same is true in a still more decided degree on the border of Switzerland; in Wurtemberg and Franconia; and generally along the borders of the Alps.

The general result of all this is, that the type of the oolitic system of the south of Europe is more calcareous; that

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Geology. of the north of Europe more arenaceo-argillaceous. The former has the air of an oceanic or deep-sea deposit, little disturbed by currents of water; the latter was accumulated under the predominant influence of littoral agitation. In most cases, indeed, but not universally, the specially argillaceous lias formation is distinguishable (even among the Alps and around Auvergne) from the specially calcareous upper oolites; the middle part of the system (Bath oolite formation) is the most variable, and the uppermost formation (Wealden rocks) is merely local.

Organic Remains.—It is impossible to say with certainty over what extent in extra-European countries the oolitic system spreads, because of the great alterations which mixed secondary rocks experience near the axes of mountain elevation. Thus the description of the thick limestone overlying red sandstones, on the banks of the Lakes of Como and Lecco (De la Beche, *Geol. Manual*), would be insufficient to make us recognise the oolitic system, but for the additional evidence afforded by certain fossils. The lias of the Swiss and Austrian Alps could not be satisfactorily understood without their aid (Necker and Murchison's Notices); nor could the singular alternations of granular limestones, micaceous slate, &c. of the Tarentaise (M. Brochant), and the problematical rocks of Piedmont (M. De Beaumont), be referred to the lias, but for the belemnites which occur abundantly among them. It is true, that here a singular anomaly occurs with respect to the organic remains, for the belemnites of the lias are found both above and below a great number of plants analogous to those of the ancient coal-measures! But this ought not greatly to surprise us. There is nothing known in geology which should forbid an admission that particular localities of land might enjoy an immunity from the effect of those causes which wrought periodical changes in the physical conditions and organic inhabitants of the sea.

The plants of this anomalous series may be viewed as a remainder of the vegetation of the era of coal deposits, transferred to a sea full of organic beings of the earliest oolitic era.

The importance justly attached to the study of organic exuviae has been overrated by some of the followers of Mr Smith, and wholly misunderstood by some of the opponents of his views. We, who have known intimately the principles really advanced and acted on by that distinguished man, may be permitted to say this, and to shew what is really their nature and meaning, by investigating their application to the geological history of the oolitic rocks, the consideration of which undoubtedly suggested the whole doctrine of the identification and discrimination of strata by their imbedded organic "remains."

The local truths ascertained by Mr Smith with respect to the oolitic rocks in the neighbourhood of Bath, as appears from his works, "Stratigraphical System" and "Strata identified by organized Fossils," are these, the nomenclature being made to suit the modern arrangements:

(1.) The fossils of the oolitic system as a group, viz. the plants, zoophyta, shells, crustacea, and fishes, differ completely from the fossils similarly grouped of the cretaceous system above, and the new red sandstone and coal systems below.

(2.) The organic remains of the lias formation differ, as a group, almost absolutely from those of the Bath oolite formation, and these present points of less general difference from those of the coralline oolite formation. Thus all the formations have characteristic local distinctions in their organic remains.

(3.) Many of the individual rocks, or masses of analogous beds and layers, contain particular characteristic fossils, which never or rarely occur in other rocks.

(4.) The fossils of strata the most similar in their mineral nature, as the oolite rocks,—the sandstones,—the

clays,—are more frequently similar or identical than those of rocks differing in nature. Thus the same, or similar echinida, occur in the Bath oolite and the coralline oolite; similar, if not the same gryphæ occur in the lias clays, the Oxford clay, and the Kimmeridge clay.

These local truths are found to be applicable in all situations where the oolitic series is expanded; they are repeated on the Yorkshire coast (Geol. of Yorkshire), on the west of Scotland (Murchison), (Dorsetshire (De la Beche), in Normandy (De Caumont, &c.), south of the Ardennes (Boblaye), in Central France (Dufrenoy, &c.), in Franconia (Munster), in the south-east of France (De Beaumont, Voltz, &c.).

In generalizing these local truths Mr Smith found that, for a considerable distance north and south, the fossils of the oolitic system, as a mass (1.), were almost universally similar, and generally the same, but universally distinct from those of older or younger systems.

(2.) That the distinction of the several oolitic formations was practicable for considerable distances by the same species, or groups of fossils, which characterized them near Bath.

(3.) That the several rocks contained, at great distances, many of the same fossils which occurred in them near Bath.

Hence arose the impression that, in England, the oolitic and other strata of the same age contained the same or similar organic bodies. It was not possible for Mr Smith to state his laws as general principles universally applicable, because, originating in observation, generalized by observation, they were in no sense hypothetical;—they were inductive not deductive,—limited to things known, not extended to things unknown.

In following out Mr Smith's views, it has been found, that the proposition (1.) of the entire distinctness of the whole group of oolitic fossils from the older and newer fossils, is almost universally true; the exceptional cases mentioned along the range of the Alps, being, in fact, viewed as singular and difficult anomalies. It has also been found, that mineral masses of most contrasted types, as the argillaceous lias compared to the calcareous oolites, retain the same general features of distinction in organic remains, wherever they have yet been examined. Whole groups of the same belemnites and ammonites mark the lias of Yorkshire, Dorsetshire, and Wurtemberg. It has also been found that the geological place of several of the species selected by Mr Smith as characteristic of Bath rocks, is the same, or nearly so, in very distant situations (*Apiocrinus rotundus*, *Cidaris florigemma*, *Avicula echinata*, *Terebratula digona*, *Ostrea delta*, *Gryphæa dilatata*, *Ammonites calloviensis*, &c.); but it is also certain, that the number of these characteristic or *monochronic* fossils is continually diminishing; that the influence of geographical position is more important than was at one time imagined; that varying physical conditions exerted corresponding influence over the distribution of organic forms; that each species had a definite range of organic existence; and, finally, that identity of species is not often to be looked for at very great distances, though a remarkable general analogy and similarity of form appears still to be very extensively recognised in the same formation at every point of its range.

The abstractions used in zoological science,—the combination of species into smaller groups,—and these into larger families, are now so much improved, that the seeming complication of the results of the study of the thousands of fossil species is fast disappearing. Whole sections of fishes, ammonites, and belemnites mark the lias, others the oolites, others the chalk, while groups of terebratulæ, gryphææ, &c. mark stages more or less definite in the scale of oolitic deposition. Where the rocks come to be aggregated

Geology. together, the characters of division cease. On comparing distant regions, only the broader zoological features of the rocks can be employed with safety. On comparing contemporaneous rocks produced under different conditions, we find the effects of such conditions in the monuments of organic life; in the general conformity of organizations imbedded in contemporaneous deposits, we read the evidence of similar physical conditions over very large tracts of the globe; in the successive diversity of these organic types we see proof of the successive general changes of these conditions. Who will say that such results are unphilosophical, or inconsistent with Mr Smith's fundamental doctrine, that the successive strata were successively the bed of the sea, and contain the remains of the vegetable and animal creation then existing on the spot or in the vicinity?

The first column of the following summary of the organic remains in the oolitic system is taken from Mr de la Beche's Notes on the Geographical Distribution of Organic Remains in the Oolitic Series of England and France (*Phil. Mag.* 1830); the second column is compiled from the last edition of his *Geological Manual* (1833); the third contains the number of species of oolitic fossils in Yorkshire, from the second edition of the *Geology of Yorkshire* (1835).

Vegetable Remains, Marine,	1	3	1
Cryptogamia,	17	23	35
Gymnospermia, &c.	21	26	12+
Zoophyta, Polyparia,	49	172+	18
Crinoidea,	8	32	5
Stellerida,	2	11	1
Echinida,	22	45	16
Mollusca, Plagimyona,	165	200	115
Mesomyona,	110	141	66
Brachiopoda,	50	66	23
Gasteropoda,	95	112	48
Cephalopoda,	188	258	83
Annularia,	15	59	10+
Crustacea,	1+	15	9
Insecta,	Several	...	...
Pisces,	1+	22+	Several
Reptilia,	16+	30+	7+
	1	1	...
	712	1216	449

The deposition of the oolitic system seems to have followed upon that of the red sandstone rocks without the intervention of more than local disturbances; and it appears that, in general, few such occurrences broke the long uniformity of the periodical agencies exerted in the oolitic period. Mr Murchison has shewn that the elevation of the granitic mass of the Ord of Caithness, took place after the deposition of most of the oolitic rocks, for these are thrown into great confusion in the vicinity.

In the north of England, the only igneous rock found in connection with the oolitic system, is the great dyke which ranges from the mountain limestone near Middleton in Teesdale, through the coal-measures of Cockfield Fell; the magnesian limestone of Bolam, in Durham; across the red sandstone of the Vale of Tees; the lias of Cleveland; and the inferior oolite, Bath oolite, and intervening sandstones and clays of Eskdale and the Moorlands, near Robin Hood's Bay. In this long course of seventy miles, the dyke retains so much of a common character,—its constituent basalt is so similar,—and the line which it describes so direct, that little doubt can be entertained of the contemporaneity of its whole mass. The effects which it has produced on the strata along the whole range are of the usual kind noticed near pyrogenous rocks: coal is charred; sandstone hardened; shale bleached and indurated. Nothing of the kind is known in the south of England.

Disturbances of the Oolitic System. The disturbed state

of the strata, accompanying the elevation of the Ord of Caithness, has been already noticed. In the north of England, the unconformity of the chalk and oolite indicates a low axis of elevation, passing east and west, under the Yorkshire Wolds; and other dislocations parallel to this occur in Eskdale and other parts of the Yorkshire oolites. A similar unconformity, and nearly equal amount of disturbance is found in the Dorsetshire oolites, where, besides, are great faults of a later date. In this district, however, phenomena have been observed in the Isle of Portland, leading to the impression that a limited tract of oolites had been raised into dry land, covered with soil and prolific in trees, and again quietly submerged, so that the trees were left standing in attitude of growth, or prostrate in "the dirt-bed." This remarkable deposit has been observed by Mr Webster and other geologists; but it is to Dr Buckland and M. De la Beche that we owe a full account of the circumstances and suitable reasoning concerning them.

No. 13.

Section of the Dirt-Bed in the Isle of Portland.



"We consider a small stratum," say these geologists, "called by the workman 'dirt-bed,' to be by far the most interesting and remarkable deposit in the district. It seems to be made up of black loam, mixed with the exuviae of tropical plants, accumulated on the spot on which they grew, and preserved during a series of years in which the surface of the Portland-stone had for a time become dry land, and accumulated a soil of about a foot in thickness, composed of an admixture of earth and black vegetable matter, interspersed with slightly rounded fragments of stone, which Mr Webster ascertained to be from the lower part of the Portland series. These fragments are found to be almost co-extensive with the 'dirt-bed,' and the fact that we have yet found with them no admixture of pebbles derived from the subjacent oolites, or from any other more ancient rocks, shews that no violent rush of water from any distant region took place during the period in which these pebbles of Portland-stone were under the process of becoming slightly rounded."

This dirt-bed, as Mr Webster has stated, forms the matrix of the silicified trunks of very large coniferous trees, which are so abundant in the Isle of Portland, and are found there coextensive with the upper surface of the Portland-stone. Wherever the dirt-bed is laid open to extract the subjacent building stone, it is found to contain these silicified trees laid prostrate, partly sunk into the black earth, and partly covered by the subjacent calcareo-siliceous slate; from this slate the silix, to which the trees are now converted, must have been derived. A bed of snow falling on a modern peat-bog, and covering the upper portion of prostrate trees whose lower portion has been sunk by their weight into the substance of the peat, would represent the position of the calcareous slate which immediately covers these fossil trees in Portland.

Some of them extend to a length exceeding thirty feet, and bifurcate at their upper end; but the branches are not continuous to their extremities, and we find no trace of leaves. The leaves and small branches, and exterior parts of the trunks, had probably decayed whilst they lay exposed to air on the surface of the peat.

Amid the prostrate trees, many of which attain three or four feet in diameter, we find silicified stems of plants closely resembling the modern *Cycas* and *Zamia*; they have been

Geology. described by Professor Buckland under the name of Cycadioideæ, and are important as indicating that the temperature in which they grew was much higher than that of our present climate. We find also, at nearly the same intervals at which trees are found growing in a modern forest, an assemblage of silicified stumps or stools of large trees, *with their roots attached to the earth in which they grew.* These stumps are from one to three feet long; they are mostly erect, while a few are slightly inclined. The black earth which contains their roots seldom exceeds one foot in thickness; the upper portions of the stumps, as represented by Mr Webster, project upwards into the substance of the superjacent stone (called "soft burr" and "aish"), which gives indication of their presence by hemispherical concretions accumulated around the top of each stump of wood.

The dirt-bed is found in several places near Weymouth, and is slightly traceable in the Vale of Aylesbury, at Swindon and Tisbury.

"We consider the dirt-bed as quite decisive in forming the barrier between the Portland (marine) and Purbeck (freshwater) deposits. Its accumulation must have proceeded during a considerable portion of time, antecedently to which the districts it occupies were entirely submerged beneath the sea, and subsequently to which the water again returned to overwhelm them, first with a deposit of about 1000 feet of the semilacustrine sediments of a great estuary (including the united thickness of the Purbeck series, and the Wealden sands and clays), and afterwards with a series of marine deposits, amounting to more than 1000 feet of greensand and chalk.

Throughout the entire succession of all these changes, there is no evidence of any sudden and violent disturbance causing either elevation or depression of the Portland-stone or of the subjacent oolites. The present high inclination of all the beds is uniformly parallel to that of the beds of Purbeck-stone, greensand, and chalk, and these all seem to have been raised simultaneously by the same convulsion which elevated the axis of the Weymouth district, together with all the inclined strata in Purbeck and the Isle of Wight.

We have a measure of the duration of the period during which the surface of the Portland-stone continued in the state of dry land covered with forest, in the thickness of the dirt-bed, which has accumulated more than a foot of black earth, loaded with the wreck of its vegetation. The regular and uniform preservation of this thin bed of black earth over a distance of so many miles, shews that the change from dry land to the state of freshwater lake or estuary was not accompanied by any violent inundation or rush of water, since the loose black earth, together with the trees which lay prostrate on its surface, must inevitably have been swept away had any such violent catastrophe then-taken place."¹

Besides the true dirt-bed above described, Professor Henslow found two other argillo-carbonaceous layers lower in the rock: in one of the lower of these Dr Fitton has recently found stumps of trees of the same kind as those in the dirt-bed, apparently in the position and attitude of growth.

GENERAL VIEW OF CIRCUMSTANCES ATTENDING THE DEPOSITION OF THE OOLITIC SYSTEM.

With this example in our minds of the progress toward definite knowledge of the local conditions of land and sea

during the oolitiferous era, we may turn to a general contemplation of the subject. It is apparent from the plants found in the lias of Dorsetshire, the Bath oolite coralline oolite formations of Yorkshire, and the Portland and Wealden formations in the south of England, that land, to some extent, existed in several points about the region of the oolitiferous sea of Europe. The analogy of some of these plants to the tropical tribes of *Zamia* and *Cycas*, is sufficiently exact to warrant our belief in the analogy of the climate in which they grew; the case of the dirt-bed seems inexplicable except on the supposition of alternation of land and water without violence; a given large area was subject to gradual vertical rise and fall to the extent of 1000 feet or more, so that certainly once (perhaps thrice or more frequently), there was time allowed for the elevated bed of the sea to be covered with heaps of decaying vegetation, and the stumps of numerous large trees which it had nourished into dense forests. Can any thing more plainly teach the human intellect not to set narrow bounds to the TIME which elapsed in those numerous physical conditions which preceded the era of the creation of man and the present adaptation of the surface of the globe?

If *between* the aggregation of marine and fluviatile sediments of the Portland and Wealden formations, *the whole life of large and stately coniferous trees has elapsed*, who will revive the unworthy folly of ascribing the curious proofs of regular and orderly structure,—the rich monuments of physical changes which the earth offers to the eye of intelligent man,—to a sudden deluge or any other violent catastrophe? It is time that the blind opposition to the progress of inductive geology, based on an erroneous view of the true meaning of the Scriptures, derived from days of ignorance, should be wholly abandoned; and perhaps the consideration of *the proof* furnished in the Isle of Portland may be sufficient to relieve at least some of the unreasonable pressure which geology feels from sources where it should meet with hearty encouragement.

We do not at present concede that the equisetiform plants which stand erect in the sandstones between Whitby and Scarborough grew on the spot where they are now found; nor is it at all required to suppose that, in the Weald of Sussex, the vegetable reliquæ were the produce of that very region; on the contrary, the manner of the occurrence of the plants in both these districts appears to prove that considerable tracts of land *in some other situations* were raised above the sea, and that rivers and inundations from this land transported materials of different kinds with a certain periodicity of action from more ancient strata. In what direction, from what ranges of uplifted land these rivers flowed, cannot perhaps be said; perhaps no land *now* above the waters yielded the sands and clays and calcareous layers to the Weald of Sussex, the moors of Yorkshire, the borders of Sutherland and Argyle, or the northern oolites of Westphalia. Yet some arguments might be adduced, especially the analogy of mineral composition, to shew the probability of anciently elevated coal strata having been the source of these sandy interpolations. At all events, they are composed of matter swept by fresh water from the land into lakes, estuaries, or the sea, for the plants and shells found with them permit no other inference. These, then, if marine, are littoral deposits; but the series of oolitic limestones, in which they form anomalous local and irregular terms, were certainly for the most part deposited in situations considerably removed from the agitation of coasts and the intermixture of fresh water. This their arrangement, freedom from conglomerates, perfection of organic contents, and simplicity of composition, fully

¹ *Geological Transactions*, second series, vol. ii.

Geology. prove. Particular beds undoubtedly (especially the top of the rocks) have suffered agitation.

The concretionary structure of these limestones is imitated in modern times only in situations where carbonate of lime is separated from chemical solution in water (Carlsbad). If we ascribe this origin to the oolitic sediment, the concretionary aggregation of the particles may be understood as arising from molecular attraction in the mass, and, in fact, many of the spherules of oolite contain an internal nucleus of previously solidified matter, a small shell, a grain of sand, or somewhat else, capable of determining the condensation of the particles to particular centres, just as the matter of ironstone has collected into nodules round a fish-scale, a piece of fern branch, or a shell.

The periodical occurrence of clays, sands, and limestones is not less remarkable in some parts of the oolitic system than in those of older date; the Bath oolite formation is sandy at the base and sandy at the top; the coralline oolite has superior and inferior sandstones, and the same is the case with the Portland oolite where the series is complete, (Vale of Aylesbury). The clays of this series appear to be in a considerable degree independent of the compound terms (of limestone and sandstone), and thus furnish means for an easy and natural division of the English oolites, which fail in various parts of southern Europe.

CRETACEOUS SYSTEM.

Geographical Extent.—In general we may perceive, as the several systems of strata pass under review, that the areas which they respectively occupy are defined by narrower boundaries, and that these approximate more and more to the present distribution of the basins of the sea. The north-eastward ranges of the oolitic strata of England, sloping gently to the east and south-east, are covered on their declining surfaces by ranges of chalk and greensand, which nowhere ascend to so great heights as the oolites which rise from beneath them. The cretaceous system is unconformed to the oolites at only two points in England, viz. in Yorkshire and Dorsetshire, and round the basin of Paris and in the south of France the same conformity of the two systems is found to prevail.

It thus becomes easy to trace the boundary of the cretaceous rocks by referring to the outline of the oolites. The chalk and its associated beds pass from Yorkshire through Lincolnshire, Norfolk, Suffolk, Hertfordshire, Bedfordshire, Buckinghamshire, Oxfordshire, Wiltshire, to Dorsetshire, always presenting a noble front of rounded hills to the west and north-west. Thence they return to the east through the isle of Purbeck and the Isle of Wight, offering a front to the south, while the broad inland surfaces, which are included between the Isle of Wight and the Hertfordshire Hills, are formed into two parallel synclinal troughs (the vales of London and of Hampshire), separated by one great anticlinal axis passing from Wiltshire to the coast of Kent, and continued into France in the district of Boulogne. The anticlinal axis alluded to changes through Sussex into a great denudation, or valley of elevation, exposing the Wealden formation in the centre, with escarp-

ments of the cretaceous system on the north, south, and west in England, and on the east in France.

Hence, in general terms, we may say the chalk of England is distinctly related in escarpments and slopes to the present German Ocean and the eastern part of the English Channel. Were the level of the sea raised three hundred feet, its coast line would in all the eastern and south-eastern parts of England be parallel to escarpments of chalk.

The long range of chalk escarpment is too obvious a feature in the physical geography of England to have escaped notice; and in the infancy of geology we find Lister observing on its great extent and continuation with similar characters into France. It does not occur in Scotland, and in Ireland is confined to the north-eastern portion, where it rests on greensand, lias, red sandstone, and coal-measures.

In France, the cretaceous system, commencing at Calais, opposite the Kentish margin of the great anticlinal denudation of the Weald, sweeps in a vast circle round Paris by Lille, Chalons, Troyes, Saumur, and Le Mans, to the embouchure of the Seine; thus appearing as a great southward branch of the English chalk system, formed in a bay of the then ocean, which was defined between the mountains of Brittany, La Vendee, Auvergne, the French Jura, and the Ardennes.

From this great area (principally chalk) a broad expanded but mostly subterranean mass of cretaceous strata extends along the north side of the Ardennes and the valley of the Meuse, and continues (seen only at intervals at the surface) along the northern border of high ground in Germany, from Essen to Paderborn, turning as that border turns to Osnaburg, and then returning through Hanover and Brunswick. It reappears along the range of the Carpathians, and in some parts of the interior of the great tertiary plains which stretch to the north into Russia, and to the east to the Black Sea. In Denmark and Scania and along the Baltic (Isle of Rugen) chalk occurs in its usual character.

Along the northern and southern flanks of the Alps some beds of the cretaceous system range extensively, but not so clearly distinguished from the subjacent or superior strata as usual. Along the Pyrenees, however, the chalk system is very fully developed, and has been uplifted to great elevations by disturbances of comparatively recent date. In the south of Spain also chalk with flint occurs. In America rocks of the cretaceous period are abundant along the eastern side of the United States, particularly in New Jersey, along the coasts of the Carolinas, in Georgia, Florida, and Alabama,¹ but true chalk is either wholly unknown or at least very rare.

Succession of Deposits.—In different parts of the geographical area above noticed, the cretaceous system differs considerably; yet, as in the case of the oolitic rocks, extreme differences from a common type are very limited, and evidently caused by local conditions, which insulated to a certain degree particular parts of the sea from the influence of the general agencies at work. If we take as a standard of comparison the complete English series, we shall find the following conspection of its local variations useful.

Yorkshire.	Lincolnshire.	Cambridgeshire.	Wiltshire.	South of England.
d. e. White chalk. Red chalk. b. Clays, green and blue.	d. e. White chalk. Red chalk. a. Green and iron sand, and calcareous beds.	e. Flinty chalk. d. Hard chalk. c. Chalk marl. b. Golt. a. Ironsand.	e. Soft chalk. d. Hard chalk. c. Greensand. b. Blue marl. a. Irony sand.	e. Flinty chalk. d. Hard chalk. c. Chalk marl and greensand. b. Golt. a. Lower green or iron-sand and limestone.

¹ Rogers in *Report of British Association for 1834.*

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Thus it appears that the most complete section is to be found in the south of England: the upper green sand losing itself very quickly to the north, the lower green or iron sand also vanishing north of Lincolnshire, and the golt and chalk constituting a binary instead of quinary system. The most constant of all the terms in this system in England are the upper portions of the chalk.

The section of this system in the north of Ireland (neighbourhood of Belfast) yields chalk, greensand, and golt. In the north of France generally the same five terms are found as in the south of England, though the golt is less distinct than in England, and the two sandy beds not so well defined. In the country north of the Ardennes and bordering on the Meuse, the chalky system, though less complete in the lower part (except about Aix la Chapelle), is much more developed in the upper part. In fact, a considerable mass of coarse, sandy, calcareous rocks, which is not really chalk, forming the hill of St Peter, near Maestricht, lies upon the ordinary cretaceous rocks of Belgium, and, both by its mineral and organic contents, offers a real though incomplete transition to the tertiary series of strata.

In the north of Germany both the chalky rocks above and the greensands below (Quadersandstein of Pirna, and other parts of Saxony adjoining the Erzgebirge) conform in many particulars to the English type. In the Carpathians the greensands predominate so as to constitute nearly the whole system. In the Alps, likewise, this is the case to a great extent, and it appears worthy of remark, 1st, that in the Saleve and parts of the Jura there is a real alternation of greensands of the cretaceous type with the upper limestones of the oolite formation; 2d, that in particular parts of the north flanks of the Alps there appears to be a blending of the characters of the cretaceous and tertiary rocks (no chalk being found), so that it is hard to say where the line should be drawn.¹ This transition, as it is called, from the cretaceous to the tertiary strata is very different from that previously noticed at Maestricht, and seems to be due to an *insulation* of the Gosau and other districts, from the influence of the physical changes which elsewhere happened at the close of the secondary period, while the Maestricht transition may be viewed as one of the few monuments left to declare the nature of those changes.

In North America the most characteristic deposit, as along the Alps, is greensand, associated with limestones, compared to oolites in New Jersey, having a more chalky aspect in Florida and Alabama, where it assumes important features, but without real chalk or true flints. Some of the deposits in New Jersey resemble the lower green or iron sands of England.

It is thus rendered evident that the English type is more or less applicable to the greater portions of the earth's surface where the cretaceous system has been recognised; that the lower parts of the system are generally sandy, the upper parts often calcareous, but that the development of these two groups is not proportional nor depending on the same centres of influence. In the north of Europe the upper group seems generally to predominate, but in the middle of Europe the greensand system is more expanded and regular; in the northern parts of the United States the greensand abounds, in the southern calcareous rocks are more important. Yet upon the whole it must be granted that the agencies concerned in producing the cretaceous system were more extensive and uniform than those by which the oolites were accumulated.

Two formations are almost universally admitted as constituting the cretaceous system.

The Chalk Formation, named from the most character-

istic mineral substance: thickness 600 feet. It includes the following groups:—Maestricht beds, upper or flinty chalk, middle or hard chalk, lower chalk or chalk marl.

The Greensand Formation, commonly abounding in a green silicate of iron: thickness 600 feet. It includes upper greensand, &c. golt or blue marly clay, lower green or ironsand, with beds of sandy or chalky limestone.

Stratification.—In this system of strata, so evidently of watery origin, stratification, if Playfair's definition were adopted ("strata can only be formed by seams which are parallel throughout the entire mass") almost never occurs! In very many instances the chalk and greensand masses shew no more of stratification such as this definition requires than the primary rocks; but the cause is very different. Chalk differs remarkably in its composition and structure from most other calcareous deposits. It is generally an earthy, that is, feebly aggregated mass; it is seldom laminated like argillaceous limestones, unless where it is harder than usual, as for example on the Yorkshire coast and in some parts of the Isle of Wight. It contains evidence of consecutive deposition from a watery liquid as complete as any other rock. In general we find through a great mass of chalk a number of nodules of flint, variously shaped, but disposed in certain layers which are almost exactly parallel to one another, and to the bounding surface of the rock, and at equal distances, three to six feet. These serve to mark the successive deposits of the calcareous mass; and from the frequent occurrence of zoophytic remains in these nodules, especially in the south of England, it appears probable that the siliceous matter was separated from the calcareous, and collected round these bodies, by that molecular attraction which has been previously noticed in nodules of ironstone and spherules of oolite. We may suppose, therefore, with Dr Buckland, an intermitting but abundant deposition of mingled carbonate of lime and silica, nearly equal quantities in each successive deposition, and that the silica was specially attracted to local centres by organic and other solidified masses. This of course applies only to the flinty chalk, which in the south of England is generally at the upper part, but in Yorkshire and at Havre flints are rather characteristic of the middle and lower parts of the mass.

The greensand formation shews the most complete stratification parallel to its bounding surfaces in those parts where the argillaceous golt and calcareous layers (*e. g.* in the vicinity of Folkstone and at the back of the Isle of Wight) vary the series of arenaceous aggregates. More regular stratification is nowhere to be seen than under such conditions. But where these divisions vanish, as in the western part of the great Wealden denudation (about Hazlemere, Leith Hill, Ryegate) the case is wholly different. The great mass of sand then exhibits little regularity of lamination, and besides is traversed by abundance of iron plates and shells in various directions, which render it nearly impossible to find any seams passing through the mass parallel to the bounding surfaces. In such a case, then, the nomenclature of Mr Smith coincides with the definition of Playfair, and several hundred feet of irregularly laminated sand constitute but one stratum.

Yet even in this extreme case the interrupted layers and nodules of chert (analogous to the flints in chalk) indicate the succession of deposits, and shew us that with respect to rocks of watery origin the adherence to the definition of stratification commonly received is likely to close the eyes of the observer on many more important matters.

The golt beds are generally laminated as other argillaceous deposits.

Organic remains occur in all the beds of the cretaceous

¹ Murchison, Boué, and others, on the Gosau deposits, in *Geol. Trans.* &c.

Geology. ous system, and there is a considerable conformity in the lists which have been composed of the contents of the greensand and chalk formations. It is also observed that a considerable proportion of the organic remains which are found in a certain member of the system in England, also occurs in the same in France and Germany; that a small number of fossils may even be esteemed characteristic of the chalk, and others of the greensand formation. Locally, the several minor groups, and even particular layers, are distinguishable by their organic contents. But if we seek to apply this rule beyond the continent of Europe, nothing but disappointment ensues. In Egypt the chalky rocks contain different fossils from those which are known in England. Even the Scaglia of the southern faces of the Alps could not be identified by fossils with the chalk of England, much less could the greensand and chalky rocks of America, in the absence of other evidence, be referred to the cretaceous system by comparing the catalogue of species of organic remains.

What would be the feelings of a geologist accustomed to believe in the occurrence of particular *characteristic forms* at every step in the range of a certain rock, on finding in the cretaceous rocks of America, which contain 108 species of clearly defined organic remains, only two which are identical with those in the contemporaneous European rocks? ¹ Yet in this we see only the illustration of a truth becoming every day more evident,—the measure of the influence of local physical differences; and instead of feeling dismay at the loss of an (imaginary) infallible guide, we ought to be alive to the investigation of the *problem of contemporaneous difference* which this and other facts enunciate. There is still a remarkable *analogy* of the species buried on the two sides of the Atlantic during the cretaceous period. Exogyrae, gryphae, baculites, belemnites, scaphites, ammonites, occur in America, as well as in the European greensand and chalky limestones; and it is possible that the specific differences of the organic forms may have been overrated, nothing being more difficult to define than the *natural limits of organic variation*.

In the following table, summaries of the invertebral organic remains of the cretaceous system mentioned by the authors of several works on the Geology of Sussex, Norfolk, Yorkshire, and Paris, are compared with a general catalogue of European fossils in this system, given by Mr De la Beche. In the Sussex and Norfolk catalogues, the numbers are in excess, because the same species has been counted in several beds of the system.

	General Catalogue.	In the Geology of			
		Sussex.	Yorkshire.	Paris.	Norfolk.
Polyparia, . . .	146	26	21	1	32
Radiaria, . . .	85	29	16	10	34
Conch. Plagim.	87	32	13	4	100
Mesom.	122	46	8	19	
Rudista,	23	...	...	...	
Brach.	67	21	Bra. 11	13	
Gasteropoda, .	56	31	8	4	40
Cephalopoda .	107	60	29	13	
Crustacea, . .	11	13	3	...	1
Annulosa, . .	30	11	3	2	22
Cirripeda, . .	2	1	3	2	4

The distribution of the organic remains in the chalk and greensand formations, may be best illustrated from the geology of Sussex and the geology of Yorkshire.

	Chalk Formation.		Greensand Formation.	
	Sussex	Yorkshire.	Sussex.	Yorkshire.
Zoophyta, generally, . .	48	31	7	5
Conchifera, generally, .	57	10	46	22
Mollusca, generally, . .	54	4	37	3

The small number of conchifera and mollusca in the Yorkshire chalk is remarkable.

Igneous Rocks.—In England, no rock of igneous origin is associated with the chalk or greensand. Such occurrences are less rare on the continent of Europe, among the Pyrenees and the Alps: at Weinbohla, on the Danube, it is covered by sienitic rock. But the most remarkable occurrence is in the north-east of Ireland, where the chalk is almost universally covered by stratiform greenstone, basalt, and ochry rock, and traversed at several points by dykes of similar rocks, and in one place (Murloch Bay) entangled with a sienitic rock. A satisfactory notion of the nature of the mass of igneous rocks, which, in this part of Ireland, occupies nearly all the space to the east of a line from the south-eastern angle of Lough Neagh to the mouth of Lough Foyle, and in almost all parts rest on chalk and greensand, may be gathered from Dr Richardson's section of the cliffs near the Giant's Causeway.

Feet.

- 60 Basalt, rudely columnar.
- 9 Red ochre, or bole.
- 60 Basalt, irregularly prismatic.
- 7 Basalt, columnar.
- 8 Of a nature intermediate between bole and basalt.
- 10 Basalt, coarsely columnar.
- 54 Basalt, columnar, constituting the upper range of pillars at Bengore Head.
- 54 Basalt, irregularly prismatic. In this the wacke and wood-coal of Port Nocker.
- 44 Basalt, columnar, forming the Causeway.
- 22 Red bole, or ochre.
- 80 Tabular basalt, and thin seams of bole.
- 88 Do. occasionally containing zeolite.

The basaltic dykes which pass through the chalk in the island of Rathlin, and other places, convert it into granular crystallized limestone (close to the dyke *largely* crystallized), from which extreme change the effects diminish in proportion to the distance from the dyke, through the stages of small granular, arenaceous, and compact stone, to the ordinary chalk. (The Irish chalk is more close-grained than the English.) The colour of the chalk is altered also; near the dyke very brown, at a certain distance bluish, further off yellowish.² It is not improbable that much of the basaltic formation of the western coasts of Scotland, including the magnificent pillared rocks of Staffa (see the very correct engravings annexed), are of the same date as the Causeway rocks.

Disturbance.—Throughout England there is little or no proof of any considerable disturbing movements following upon the deposition of the chalk; yet, from the character of the lower tertiary strata of England which rest upon the chalk, it appears undoubted that considerable agitation of water occurred, for the surface of the chalk was wasted, and conglomerate or pebble beds formed of the detrital flints. The mass of igneous rocks poured out on the chalk of Ireland, is of too indefinite an age to be appealed to as proof of convulsions in that quarter. But on the continent of Europe, De Beaumont assigns to this period his Pyre-

¹ Bruyer and Conybeare in *Geol. Trans.*

² Rogers in *Report to the British Association.*

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neo-apennine system of convulsion,—the elevation of the Pyrenees, Carpathians, Northern Apennines, Dalmatia, and the Morea, in lines ranging parallel to a great circle on the sphere through Natchez and the Persian Gulf. It appears also that some disturbances which happened *during* the cretaceous era, are traceable in Mont Viso and the Western Alps. Supposing the Pyreneo-apennine system to be principally, if not wholly referrible to this period, we seem to behold a reason for the agitation of the shores of the English chalk basin; the distant convulsion might sufficiently explain this local and transient agitation, but, in fact, it is very probable that the English chalk underwent a gradual local elevation, which contracted the area of the bordering seas, and formed shores and dry land slopes of chalk, to be wasted by the waves, the rivers, and the rains. The pebble-beds of the tertiaries which rest on the chalk of England, do indeed more exactly correspond to such an origin than to the effect of sudden and violent disturbance.

TERTIARY STRATA.

Base of the Strata.—We have seen that during the long and yet unmeasured period which elapsed during the accumulation of the secondary strata, elevation of the land continually happened by gradual forces, and sometimes by violent disturbance. The most striking case of the latter is the general disruption of the coal system, at least before the completion of the red sandstone deposition. Of the gradual elevation of strata, almost the whole series furnishes continual proof. Hence it is, that the oolitic rocks follow one another so exactly in their geographical boundaries, retiring continually into smaller and narrower areas, as the elevation of the old land proceeded. In the continuation of the process, the greensand and chalk form, at least in England and France, a still interior band of deposits, which mark the gradual contraction of the seas, that is, the gradual uprising of the land.

The tertiary strata have, in general, to the chalk the same geographical relations as that to the oolites. Throughout England, the chalk is the base of all the tertiary strata. In France this is generally the case, and almost universally so for the marine tertiaries. In the north of Germany, along the north and south slopes of the Alps, and in the basin of the Danube, this is at least very extensively true. In North America, the general basis of the tertiaries is the cretaceous formation. On more close inquiry, it appears, however, that the tertiary strata are seldom exactly conformed to the stratification of the chalk; that any thing like a gradation or alternation of the cretaceous into tertiary deposits, is rarely known; that the organic remains of the one group differ almost wholly and absolutely, except in the south of France, at Maestricht, &c., and constitute two distinct groups of created life. Hence it has become a popular opinion, that with the secondary strata ended a certain general condition of the globe, and with the tertiaries commenced a totally new arrangement. Moreover, because we find the marine tertiary strata distinctly related, in geographical expansion, to the present basins and arms of the ocean; as the organic remains which they contain are similar, and, in rocks of later date, identical to those of the existing races in the sea and on the land; and as the tertiary sediments are of a nature very analogous to the daily products of the sea, estuaries, tide-rivers, and lakes,—there is but a step farther to unite the tertiary era with the historical period of the globe, and to place the commencement of the actual creation or arrangement of organic nature at the epoch immediately following the chalk. For these and other reasons, the tertiary strata are of great interest. They admit of a clear comparison, in all respects, with the effects which daily occur before our eyes; and thus facili-

tate our inquiry into the conditions of nature in earlier periods. They furnish the principal arguments on which Mr Lyell rests his doctrines of the continual uniformity of the measure of terrestrial agencies, as the older strata have long done to those who maintain that, in the construction of the crust of the globe, periods of ordinary action have been broken by crises of unusual violence.

Nature of the Tertiary Strata.—In very few instances, during our survey of the products of earlier nature, have we found reason to admit the deposition of strata in any other waters than those of the sea, in its depths and along its shores. The coal deposits of the north of England generally, belong to the class of estuary formations, in which the influence of the sea was often less and never more sensible than in the bed of a tide-river, where the water is only brackish. At intervals, indeed (Yorkshire coal-field), when great distant disturbance or local change of the circumstances occurred, the influence of the sea has returned and produced its usual effects, leaving, as monuments of its short dominion, peculiar kinds of animal exuviae.

The oolitic formation on the Yorkshire coast and in Sutherland proves plainly enough the local addition of fresh waters and spoils from the land; the Wealden formation indicates, in like manner, a wide estuary fed by some river, on whose banks gigantic reptiles or tropical plants abounded; but nothing has yet been shewn with respect to any carboniferous or oolitic deposit, which renders necessary the supposition of *lacustrine or purely fresh-water deposits*. Communication with the sea from the basins of the coal deposits, and from the Wealden beds, is apparently indispensable in explaining the occurrence of particular sorts of fishes in these strata, and not in any respect inconsistent with the evidence of the molluscan exuviae. The most plausible arguments for fresh-water deposits among the older strata, are advanced by Dr Hibbert in his description of the Burdiehouse fossils, and by Mr Murchison in his notices of Shropshire coal-fields. Without in the least wishing to intimate that the influence of fresh-water in accumulating the materials of the strata is most conspicuous in the newer strata,—an inference not justifiable by the facts,—it is to be remarked, that the deposition of stratified rocks in limited basins of fresh-water is a phenomenon almost characteristic of the tertiary period.

The same tracts of watery surface beneath which the coal-field of Yorkshire was formed suffered alternate influence of the sea and river water. The estuary of the Wealden, and the coal deposit of the oolitic hills, were alike formed upon the bed of formerly deep seas, and at a later period deep sea again covered the same area: in a certain sense, the deposits of fresh and salt water alternate in several secondary formations. But in the tertiary strata, this phenomenon of alternating marine and fresh-water products is more decided and remarkable. In the basin of Paris, at least two fresh-water and two marine deposits alternate in the tertiary series. Alternations of really fresh-water and really marine products happen in the south of France, the valley of the Rhine, in Hungary, and the Isle of Wight. In these cases the explanation is possible, without supposing repeated upliftings and submersions of the land—of which, from other phenomena, there is no evidence—by merely conceiving estuaries or expansions of water, such that the influence of rivers and the sea might alternately predominate, just as, in fact, we know to have happened, even in historical times, in the marshes of East Norfolk,—and as must have often occurred in similar tracts at the mouths of rivers where variable sand-banks abound, and alter the direction of littoral currents. At some later epoch, the whole bed of the estuary has been uplifted to its present elevation above the sea.

Nature of the Marine and Fresh-water Deposits.—It is a remarkable confirmation of the views of modern geologists, that a great portion of the substance of sedimentary strata

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Geology. was swept down to the sea by inundations and other watery forces operating on the surface of the dry land,—that the marine and fresh-water sediments of the tertiary era have so much general analogy. In each we have calcareous, argillaceous, and arenaceous deposits, alternating,—stratified, laminated, in a similar manner; the organic exuviae are similarly disposed in the beds, and, but from the character of these, we could not in general venture to pronounce upon the nature of the water in which the beds were deposited. Some distinction is, however, to be traced; the marine arenaceous sediments are thicker and more confused than those of fresh-water; the marine clays are less minutely laminated. It may be remarked, in general, that limestones and fine light-coloured clays constitute the principal mass of the fresh-water sediments; while sands, and blue and variously-coloured clays more particularly mark the marine depositions. The latter appear like the products of littoral agitation, as if the wearing of cliffs of older strata had furnished the materials of these newer rocks; while the former resemble the accumulations from the wasting surface of chalky and argillaceous countries. This is more particularly the case in the Isle of Wight, where the coloured sands of the marine tertiaries might seem really to have drifted only a few miles from the equally-coloured sands of the greensand and Wealden formations; while the fresh-water marls and limestone may be imagined to have been added from a wasting surface of chalk hills.

SCALE OF GEOLOGICAL TIME.

In all our former inquiries, the successive geological periods have been arranged by the marine deposits and marine fossils; and the same plan must be followed in these tertiary rocks if we wish to preserve consistency. The true plan of comparing the tertiary and earlier strata, in reference to chronology, is to reject the lacustrine and estuary deposits, and the remains of land and fresh-water animals and plants, and confine ourselves to the marine productions merely. Had this prudence been duly observed in geological reasoning, much inconsistency and contradiction might have been avoided; the fresh-water depositions (which are merely local terms in the series of strata), would not have been appealed to in proof of the relative ages of marine deposits, nor should we have been led, by the occurrence of a few exuviae of land mammalia, into conclusions at variance with the evidence of marine invertebrata, which are the true indices of past geological time.

Succession of time, as determined by marine productions, is the true scale of geological classification; and it is clear that the fresh-water strata of any series can only be determined in age by their relations to the marine; also, as the laws of changes of organic life, which are gradually unfolded by geology, are founded, in the first instance at least, on the facts known with reference to marine fossils, it is to this standard that the independent series of analogous changes on the land must be referred. The *rate* of such changes on the land, however real and regular, may have been wholly different from that in the sea, and must be studied apart. This reasoning leads directly to a classification of the phenomena of tertiary deposits under three heads,—

The Marine deposits,

The Fluvatile deposits, alternating with marine deposits,

The Lacustrine deposits;

a classification, however, which is better suited to a philosophical review of the results of investigation than to a description of the phenomena, for these are often intimately associated.

BRITISH MARINE TERTIARY DEPOSITS.

Geographical Extent.—In Europe, the area covered by

marine tertiaries is scarcely inferior to that occupied by either the primary or secondary series. Ireland and Scotland, and all their dependent islands, are wholly deficient in these strata, unless we choose to make exceptions in favour of uplifted beaches whose date is yet uncertain, like the terraces on the sides of the Forth, and the shelly beds on the coast of Wexford. No tertiaries occur in Wales, unless the shelly gravel on the north face of Snowdonia be of this date; neither do any traces of these deposits occur on the coast of England further north than Bridlington in Yorkshire, nor to the west of the Isle of Purbeck. Raised beaches, however, are met with beyond these boundaries. Inland, the tertiaries follow a line parallel to the chalk escarpment in all its great flexures, and along the east and west axes of dislocation. There are, consequently, two great troughs or basins of tertiary strata, viz. those of London and Hampshire, both ranging east and west.

Succession of Strata.—It is remarkable that in these two basins principally, though not exclusively, lie the lower members of the tertiary series of England, while other members have mostly a local distribution, depending on different circumstances. No complete type of the English series can be had at any one locality, not even in the Isle of Wight, where alone the fresh-water formations are distinctly seen. To compose a complete section, we must add together the strata of Norfolk and Suffolk, the beds of the London basin, and the varied deposits of the Isle of Wight. We thus find that the marine deposits of England range themselves in three groups, viz.

Upper group or Crag,.....Generally arenaceous.

Middle group or London Clay, ...Mostly argillaceous.

Lower group, or plastic clay, &c...Clays and sands.

Of these the upper group occurs only in Norfolk, Suffolk, and Essex (unless the tertiaries of Bridlington may be classed with it); the lower group is confined to the basins of London and Hampshire. The following is a sketch of the state of knowledge concerning each of these groups.

The Lower Group of Plastic Clays and Sands is best seen in the Isle of Wight, where its characters are easily examined at Alum Bay, at the west of the island. Mr Webster, who first described this interesting spot, gives the following succession of the beds lying next to chalk, all vertical or nearly so. The chalk is covered by a calcareous marly bed, probably not related to the tertiary deposit. Then follow 60 feet of green, red, and yellow sand; 200 feet of dark blue clay, with greensand and septaria, and a few shells; 321 feet of variously-coloured sands; 543 feet of pipe-clays and sands of various colours, which, by crumbling and exposing fresh faces, shew very bright and splendid tints of white, yellow, orange, red, green, grey, and black. Near the middle, lignite is found in these beds (with remains of fruit); and in the higher part toward the north, five other beds of lignite occur, each about a foot thick; rolled black flints in yellow sand. (Dark coloured clay 250 feet thick, with greensand and septaria, and abundance of shells of the London clay closes the series.) Reduced in thickness, these sandy and argillaceous layers continue both east and west. At Poole they yield valuable pipe-clay and sands.

In the basin of London the plastic clays and sands vary in thickness and quality, but present general analogies with those of the Isle of Wight, in the variously-coloured sands and clays of Reading, layers of worn flint pebbles (Blackheath), mostly very small, and a few beds of shelly clay (Woolwich.) It is in most places somewhat confused in lamination, full of indications of littoral agitation, and apparently accumulated with considerable rapidity by very limited agencies. Whence have come the masses of sandy materials which compose this deposit in the two basins in question? We have already said that in the Isle of Wight

Geology. it appeared as if the tertiary sands had been derived from the ruins of the very similar subcretaceous rocks of the vicinity. Perhaps the hypothesis may be extended to the basin of London, (once certainly united with that of Hampshire.) Mr Lyell, indeed, in reasoning on the basin of London, has proposed the ingenious hypothesis of the accumulation of all the materials of these basins from the waste of the Wealden district, assumed to be then rising gradually to encounter the ravages of the atmosphere. The evidence is not satisfactory, and the supposition involves a point of some importance not yet conceded, viz. the gradual elevation of the Wealden district. At all events, the probability is great that some uplifted greensand ranges contributed materials to the plastic clay formation.

The *Middle Group of London Clay* is most fully developed in the vale of the Thames, and best known in the vicinity of London. The numerous wells established here have shewn the inferiority of the plastic clays and sands to the London clay, and contributed to make known the characters of this great argillaceous deposit, which, in some places, is above 500 or 600 feet thick, and in Essex, at High Beach, 700 feet, according to Conybeare and Phillips.

In this great thickness of blue and brown clay is little variety, except what is caused by a few layers of nodular septaria, and toward the bottom greensands or sandstones, (which are more fully developed at Bognor on the coast of Sussex.) Laminated shelly beds also occur (Knightsbridge Well), and in the Harwich Cliff are layers of stratified limestone, (Greenough.)

Organic remains are nowhere rare in this deposit, and, in particular localities, extremely abundant; 239 species are mentioned by M. Deshayes from the London clay, principally of Hampshire and Highgate; and of these only twelve, or five per cent., have been found living in the present seas.

What is the origin of this mass of clay? Mr Lyell supposes the uplifted Weald of Kent and Sussex to have yielded the materials of the whole of the marine tertiaries to the north and south; that waste of the sandy tracts of the Weald furnished the plastic clays and sands, and the Weald clays contributed the argillaceous sediments. But this speculation can neither be advocated nor opposed except by trains of argument involving too many assumptions to be admissible in inductive geology.

The *Upper Group, or Crag Formation*, is a local deposit of a character very different from all the older strata. It consists of two parts, which, according to recent researches of Mr Charlesworth, are placed in superposition at some points on the eastern coast, particularly Ramsholt near Woodbridge. The lower part is either a loose, partially calcareous sandy mass (Ramsholt), very full of shells, and containing a considerable quantity of corals, not at all agreeing with the zoophyta of the German Ocean, or else a coarse sandy zoophytic limestone (Aldborough and Orford), in which some of the same shells occur. The thickness of the lower, or coralline crag, is not certainly known; from seven to twelve feet are exposed; it is scarcely ferruginous; shews no considerable marks of watery agitation; pebbles and rolled shells are not seen in it.

In these particulars it differs much from the upper or red crag, which shews, by its very confused, often curved, and obliquely-intersecting lamination, by its abundance of rolled pebbles, bones, and shells, proofs of having been accumulated under the influence of agitated waters. No trace of land plants occurs; in general no alternation of clay deposits is seen; and though a few bones of mammalia have been found (as in the older and quietly deposited tertiaries of Italy), there can be no doubt that the whole is

Geology. a littoral marine accumulation. The whole is very ferruginous. Shells are excessively plentiful; and in fact constitute, in some places near Woodbridge, the principal part of the mass. Corals are very rare (though not absolutely unknown); and solenostomatous gasteropoda, (including reversed whelks), very plentiful.

From the composition and character of the upper or red crag we may venture to adopt the opinion, that it is little else than an elevated beach of the German Ocean, parallel to the shore of which it is extended from north to south through the eastern parts of Norfolk and Suffolk. The coralline crag below it may be viewed as a less disturbed product of the same ocean farther toward the deep sea.

What relation does this shelly deposit bear to the actual beach and littoral bed of the German Ocean? This question brings us to a more close consideration of the organic remains of the crag, which, according to Mr Charlesworth, amount, in the collection of Mr Wood of Hasketon near Woodbridge, to 470 species, viz.—

Annulosa,	13	Conchifera,	189
Cirripeda,	11	Mollusca,	257

Of these 111 have been examined by Deshayes, and he assigns 45 of these (40.1 per cent.) to recent types mostly found in European seas. In the coralline crag Mr Charlesworth finds 350 species of testacea, and in the red crag 230; 150 are common to both the deposits; 80 are peculiar to the red crag; 200 to the coralline crag.

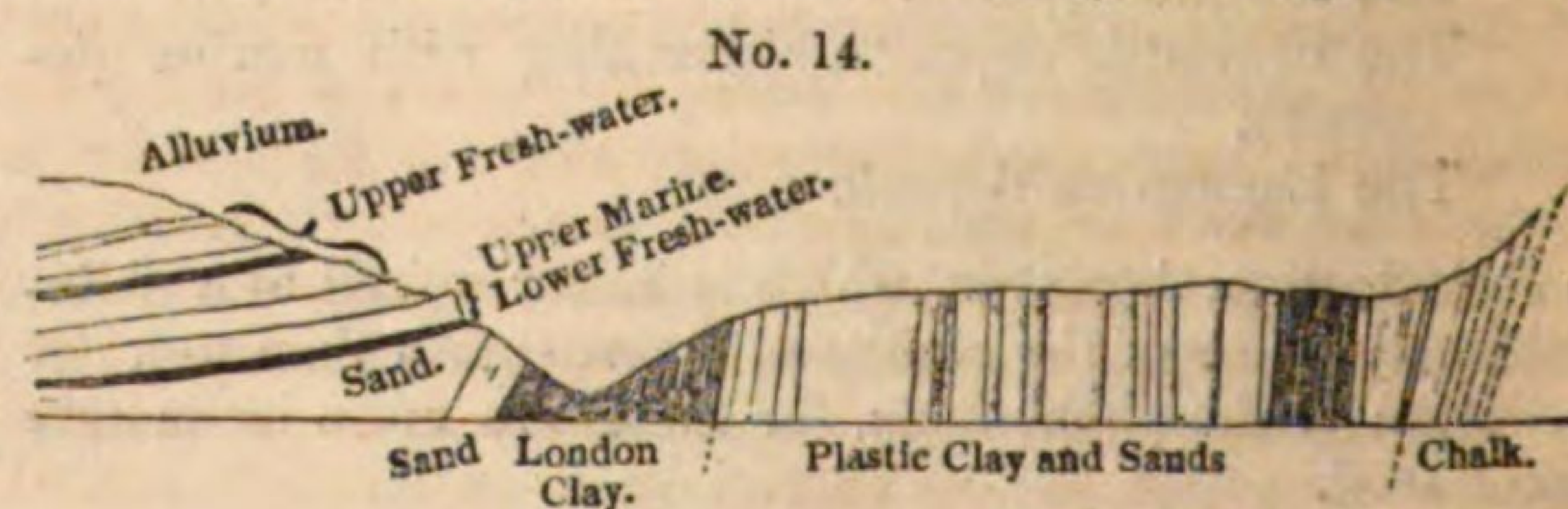
M. Deshayes' result, quoted above, was principally founded on an examination of the red crag. Lately he has also examined a portion of the shells of the coralline crag, and finds in these the same, or rather greater, proportion of recent species.¹ According to this evidence, the lower or coralline crag is to be classed with the red crag; as a somewhat anterior deposit, produced under different local conditions, but including organic exuviae which bear the same numerical relations to the present forms of marine invertebrata. In some of the Norfolk crag are *detrital fossils* from the chalk and oolitic series of rocks.

A deposit of shelly sands and clays has recently been found on the coast of Yorkshire at Bridlington Quay, which cannot at present be referred to its true place in the scale of British marine tertiaries.

The green and yellow sands and blue clays, which contain the shells, form the base of a perishing diluvial cliff; and, in the compass of a few yards' length, fifty-five species of shells have been found, besides some small cephalopoda, and several bones and teeth of fishes. Of the shells, four species are also found in the crag—five or six are identical with living species—a considerable part of the remainder are, as far as yet known, peculiar to this locality.²

BRITISH FRESH-WATER DEPOSITS.

These are confined to the Isle of Wight and part of the adjacent coast of Hampshire. Mr Webster first called public attention to them. Against the London clay mentioned in the section of Alum Bay rest a considerable mass of sands, chiefly white or light coloured, which gradually lose the verticality of the dislocated beds here, and turn so as to become almost perfectly horizontal. (See Diag. No. 14.)



¹ Proceedings of British Association at Dublin.

² Ibid.

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Upon these lies a mass of nearly level stratified marls and limestones constituting Headen Hill. These calcareous marls, &c. constitute the fresh-water formation, and they are parted into two groups, upper and lower fresh-water beds, by an intermediate set of strata containing estuary and some really marine shells.

The *Upper Fresh-water Group* consists of thick limestone and marl beds, full of limneæ, planorbes, and other fresh-water shells; the limestone is partly compact and partly loose and *chalky*; the marls of a light greenish-yellow or blue; altogether fifty feet or more thick.

The *Middle or Estuary Group* is about thirty-six feet thick in Headen Hill; it is a greenish marl, *not materially different* from some of the fresh-water beds, and is actually crammed full of neritina, potamida, ancillaria, and many other small estuary and marine shells. A bed of oysters occurs with them in another part of the island.

The *Lower Fresh-water Group*, sixty-three feet thick in Headen Hill, is very like the upper beds (at Binstead are alternations of siliceous limestone); the lower part is a dark clay. Fresh-water shells are very numerous in particular layers. Below is white sand without fossils.

FOREIGN TERTIARY STRATA.

Though the English tertiary strata occupy but a very small space, compared to the wide extent of these strata on the continent, they are not inferior in interest to those of any district in Europe. There is a very remarkable analogy between the tertiaries of the basin of Paris and those of the basin of Hampshire, extending even to the number and circumstances of the fresh-water beds, accompanied, however, by as remarkable a difference in the composition and character of one part of the series. The following is the arrangement of the tertiary strata near Paris adopted by Cuvier and Brongniart, (*Tableaux des Terrains*).

Upper Fresh-water or Epilimnic Group, consists of two sorts of rocks, separate or in combination, viz. marly limestones with calcareous or argillaceous marls, and siliceous rocks. The former always shew tubular cavities proceeding upwards, *as if gas had passed through the sediment* while soft. The latter consist principally of the cavernous siliceous substance called French burr, in some portions of which are shells.

Upper Marine Group, consisting of sands and sandstones of various colours, and some conglomerates with a few shells and marly beds.

Lower Fresh-water, or Palæotherian Group, consisting of siliceous limestone, marls, clays, and gypsum, with a considerable number of lacustrine shells and bones of extinct pachydermata, and a few land and fresh-water plants.

Lower Marine Formation, or Calcaire grossier; a thick bedded coarse-grained shelly limestone, with abundance of marine zoophyta, shells, and fishes, some cetacea, &c. Some sandy beds accompany it, and grains of green silicate of iron.

Plastic Clays and Sands of different colours, as green, red-dish; beds of lignite in the upper part; some limited layers of detrital pebbles in the lower part; few organic remains.

It will be seen from this brief notice of the tertiaries of the basin of Paris, that they present a marked general agreement with those of Hampshire; similar plastic clays and sands below; similar alternations of fresh-water and marine strata above. Yet the particular differences are even more striking. If the general agreements indicate some predominant analogies of physical conditions, spreading each way from the English channel, these particular differences are no less instructive in shewing the essential diversity of phenomena arising from local circumstances. The lower marine formation of the Paris basin corresponds in geological age with the London clay, and contains the same organic fossils, with many others; but it is a calca-

reous, and not argillaceous, deposit. The fresh-water formations differ considerably from those of the Isle of Wight, by the prevalence of siliceous concretions and beds, the local production of gypsum and other circumstances.

It appears by no means unlikely that the lower fresh-water beds of the Paris basin are really the equivalent of both the fresh-water deposits of the Isle of Wight, while the upper Parisian deposit from fresh water has more the air of a really lacustrine accumulation, and is the most recent deposit in the district.

The tertiary series in the south of France has a general analogy to that of the vicinity of Paris; but the differences are great, and, upon the whole, tend to produce a correspondence with that of Italy. The following is the arrangement of beds:—

Upper Fresh-water Lacustrine deposit, containing shells, insects, and plants.

Upper marine beds.

(3.) *Sands*. Micaceous and light-coloured, with remains of land and marine mammalia, land and fresh-water reptiles, fishes and shells.

(2.) Marls and limestone, (*calcaire moellon*), with remains of marine mammalia, fishes, mollusca, principally in the upper beds.

(1.) Argillaceous marls, the same as the blue subapennine marls, with marine shells in abundance; terrestrial exuviae rare; an estuary bed enclosed.

Lower Fresh-water Formation. Pisolithic limestone; marly and siliceous limestones, with land and river shells; marls, silex, and slaty magnesite with gypsum, containing land and fresh-water exuviae.

Lower Marine Formation. Calcaire grossier; greensands, &c.; inferior clays, lignites, &c.

Combining the sections of the subapennine and Sicilian formations, but rejecting the superficial gravel and detritus, we have three principal terms:

Upper Subapennine, or Sicilian deposits. In the Val di Noto is the most complete section of these comparatively recent beds. The uppermost group, which rises in Castrogiovanni to 3000 feet above the sea, is calcareous, sometimes 700 or 800 feet thick, stratified, and locally solid. The organic remains are almost exclusively of recent marine species. The middle group is a white calcareous sand or yellow sand, like what is found covering the sub-apennine marls in Italy. The lowest group is a blue argillaceous marl, with numerous fossils, mostly of recent species (Dr Daubeny and Mr Lyell).

Middle Subapennine deposits. Several thousand feet thick, composed of fine laminated, argillaceous, and calcareous marls, and blue clays; with rare interpolations of lignite, sandstone, and thin limestone; abundance of organic remains, often referrible to existing marine testacea, &c., and a few instances of imbedded remains of land mammalia (Mr Lyell).

Lower Subapennines. These occur in the Superga, Piedmont, and consist of greensands and marls, resting on a conglomerate of fragments of primary rocks (Brongniart, Lyell).

The researches of Murchison and Sedgwick on the north flanks of the Austrian Alps, those of Boué in Transylvania, and of Studer in Switzerland, have yielded complete information as to the tertiary strata of these districts. The most complete section is that given by the English geologists in Lower Styria.

Uppermost group. Calcareous sand and pebble beds, calcareous grits and oolitic limestone; shells are plentiful; some of them still exist in the sea. White and blue marl, calcareous grit, white marlstone; and concretionary white limestone, containing shells.

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Middle group. Coralline limestone and marls, several hundred feet thick; organic remains of the *middle subapennines*.

Lower group. Conglomerate, with micaceo-calcareous sand and millstone; dark blue marly shale, sand, &c. Some of the shells are identical with species of the calcaire grossier and London clay; shale and sandstone with lignitic coal, containing bones of anthracotheria and fluviatile shells and plants, micaceous sandstones, grits and conglomerates of primary detritus.

Without adding to these details the sections along the Carpathians, and in the plains which extend from them to the north, we may proceed to offer a short view of the general analogies and distinctions which appear to prevail among the tertiary strata of Europe with reference to *geological time*.

Mineral Composition.—It is evident, from comparing the sections given, that no special resemblance of the strata in thickness or mineral composition can be traced, such as we have found to be frequently observable while examining the older strata. All are composed principally of calcareous, arenaceous, and argillaceous matter; but so are all the secondary strata. We do not find in the different regions compared any settled order of succession among the rocks of different nature. The English series has no marine limestone; the Parisian no thick marine clays; the subapennine deposits have little arenaceous matter. It is apparent, in fact, that the tertiary deposits vary as to their mineral composition very much more in relation to locality than to geological time,—a fact which at once subverts all hope of arranging them in geological chronology by comparison of their mineral constitution. It also leads us to infer that the deposition of tertiary strata took place in arms and gulfs of the sea, which ramified among the masses of land then raised in Europe, and derived sediments of different nature from these different lands. Hence the subalpine tertiaries have one character; those of the subapennines another; the subpyrenean a third; the Parisian a fourth; the English a fifth.

By prosecuting this research, we find, in fact, that the tertiary formation was sometimes produced in insulated seas, like the Adriatic, and the valleys of the Rhine and Danube; at other times under the influence of the general ocean, as those in the plains of the Garonne; often in basins, like the Parisian series. Thus a principle of classification is indicated, not entirely inapplicable, it is true, to the older strata, because these were also dependent on local conditions, but yet in a peculiar sense appropriate to this comparatively modern system of deposits.

It is easy, in fact, to perceive, that, by the united effect of so many systems of disturbing movements, the expanded seas, in which the older strata were deposited, had been either completely divided into separate portions, united by narrow straits, or placed under very different relations to oceanic currents and inundations from the land. In consequence, the causes of local diversity, always operating from the very commencement of geological time, approached their maximum of effect in the tertiary periods, and left among contemporaneous marine deposits very slight analogies.

Organic Remains.—But the phenomena of organic life offer us another and independent scale of comparison, which the principles of Smith, developed by the researches of Deshayes, and the reasoning of Lyell, have encouraged us to apply to the tertiary strata, for the purpose of determining in each district, those lines of contemporaneity, with-

out which geological history has no principle of combination,—no clue to general laws.

For the sake of precision in our inquiries, let us suppose, in conformity with the general bearing of all the results arrived at by investigations among the earlier strata, that the *changes of marine organic life* were, in the region of Europe, during all the tertiary periods, *proportional to the time elapsed*; and since the tertiary strata contain forms identical with living species, let us agree to form our scale of geological time, as indicated by the change of organic life, by reference to the present catalogues of invertebral animals living in the sea and fresh-waters.

According to the proportionate number (or per-centage) of fossil forms identical with living species which are found in any tertiary stratum, its date will be nearer to or further from the epoch of the commencement of the present order and arrangement of living nature. That this principle is strictly and generally true, can neither be proved nor granted; because it is neither proved nor probable that the influential circumstances according to which the changes of organic life proceeded, varied in any place, much less in all places, exactly in proportion to the time elapsed. Yet the change of organic forms is probably the most general and strict measure of time *which can be found* among the tertiary strata; and in adopting it Mr Lyell has certainly entered upon a very interesting train of inquiry, capable perhaps of even more exact application among the strata of older date, when the contemporaneous conditions of different parts of the globe were certainly more uniform than during any part of the tertiary period.

It is indeed this very diversity of local conditions that makes it extremely doubtful how far we may venture to apply to individual cases the law which perhaps may be true only of the assemblage; just as a mathematical expression for terrestrial temperature of the surface may be quite exact for the mean of a whole zone of latitude, yet not correct in any one point of the whole surface, because of different circumstances.

For example, the shores of Italy are margined by tertiary deposits, which have been raised out of the existing Mediterranean Sea, and contain many species of marine exuviae still living in that sea, and nowhere else. The vale of the Danube is also full of tertiaries, which contain many shells; but this once tertiary sea has been *wholly laid dry*, and all its *peculiar* testacea are imbedded in the earth. It is apparent that the fossils of Italian tertiaries will shew numerically greater resemblance to existing species, than those which lie in the contemporaneous deposits of the Danube, the numerical difference being in proportion to the (unknown) number of shells which in a former condition of the globe *were peculiar to that now dried tertiary sea*.

Some difficulties connected with the application of the principle to the comparison of different basins, no time can remove; others will be diminished by further research; and in almost every instance important results will arise from exact researches to test its truth in every separate basin or branch of the old tertiary sea.

We may now proceed to shew the results of the inquiry conducted by M. Deshayes, upon the supposition of the relative antiquity of tertiary beds being inversely proportioned to the per-centage of recent species among its imbedded fossils.¹

Commencing with the English tertiaries, we find from M. Deshayes, that among 111 species of shells from the Crag, 45 are living; = 40.1 per cent.; and of 239 from London clay, 12 are living; = 5 per cent.

Proceeding to the basin of Paris, it appears that among 1122 species of shells, 38 are still living; = 3.4 per cent.

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¹ Lyell's *Principles of Geology*, vol. iii. (1st Edition).

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On the Atlantic shore of France—1. At Angers, out of 166 species, 25 are still living; = 15.0 per cent. 2. In Touraine, out of 298 species, 68 are still living = 22.7 per cent. 3. In the vicinity of Bordeaux and Dax, out of 594 species, 136 are still living; = 22.9 per cent.

The subapennine series of Italy and Sicily—1. Lower subapennine (Turin), out of 97 species, 17 are still living; = 17.5 per cent. 2. Middle subapennines, out of 569 species, 238 are still living; = 41.8 per cent. 3. Upper (or Sicilian beds), out of 226 species, 216 are still living; = 95.1 per cent.

The tertiaries of the Danube and Rhine—Baden, out of 99 species, 26 are still living; = 26.2 per cent. Vienna (and north of Carpathians), out of 124 species, 35 are still living; = 28.2 per cent.

From these and some other investigations, M. Deshayes was led to group the tertiary deposits in three assemblages, viz.—The most ancient, including the Parisian and London and Hampshire beds; those of Valognes, near Cherbourg, and Belgium; Ronca and Castel Gomberto. From this series 1238 species of shells have been examined by M. Deshayes, who finds 42 of them, or 3.5 per cent. still living. To these Mr Lyell gives the name of Eocene deposits (*ἥως*, the dawn; *καινός*, recent.)

The middle assemblage includes the beds of Bordeaux, Dax, Touraine, Angers, Baden, Vienna, Hungary, Transylvania, Moravia, and the country north of the Carpathians. Ronca is also provisionally included by M. Deshayes, but, as he conjectures, it would be more properly transferred to the older division: 1155 species of shells are mentioned, of which 176 are still living, being 15.2 per cent. These are called Miocene by Mr Lyell (*μειων*, less; *καινός*).

The upper assemblage contains the fossils of Italy, Sicily, Perpignan, the Morea, and the English Crag, 770 species, of which 350 are recent, or 45.4 per cent. To these Mr Lyell gives the name of Pleiocene (*πλειων*, more, and *καινός*); but he distinguishes them into two divisions—older pleiocene, including the English crag and middle subapennines of Italy; and newer pleiocene, composed solely of the Sicilian deposits.

Mr Rogers has lately applied to the tertiaries of North America the results of Deshayes and the nomenclature of Lyell. The species are generally different on the two sides of the Atlantic, both among the tertiary fossils and living shells. The oldest American tertiaries are more analogous in their fossil contents to the secondary rocks than is found to be the case in Europe; they contain 210 species, of which hardly one is recent. The middle tertiary formations (supposed to include miocene and older pleiocene), contain 195 species, of which 40, or 21 per cent., are recent; the most recent (newer pleiocene) are very limited in extent.

Fresh-water Organic Remains of the Tertiary Era.—In the preceding account of M. Deshayes' tables and Mr Lyell's nomenclature, we have retained the numerical statements of these authors, though liable to one slight objection, the introduction of the remains of fresh-water and land mollusca. These amount to 259 species, a number too small to influence materially the resulting classification. There are of fresh-water bivalves in the fossil state, 30 species; of univalves, 151 species; and of land shells (univalves), 78;—in all 259.

Though the far greater part of these belong to species no longer in existence, all are included in the same genera, and there is no particular reason to be gathered from them for admitting that the climate or local conditions of the land of Europe during the tertiary era was very different from what is now experienced.

Any one who knows the variation of the forms of existing Limnæ and Unionidæ in fresh waters of different nature and degrees of agitation, may be forgiven if he does not at once perceive and acknowledge the minute distinc-

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tions which really exist between the tertiary and existing fresh-water shells. A small number of fresh-water plants (Characeæ, Equisetaceæ), occurs in the calcareous deposits of the basin of Paris, and great masses of lignite, derived from land plants in the sands and sandstones of Switzerland, France, and England, and they all shew great analogy to existing plants.

Terrestrial Organic Remains of the Tertiary Era. These consist of a few land plants and mollusca, with a considerable number of the remains of mammalia. In the fresh-water deposits of Hampshire, Paris, &c. belonging to the cocene period, the bones of certain extinct races of quadrupeds occur, as the palæotherium, anoplotherium, lophiodon, dichobune, &c.; with living genera, as vespertilio, canis, sciurus. In the lignite beds of Styria and Switzerland, anthracotheria, beavers, &c. abound; in the superficial lacustrine beds of central France, Oeningen, &c. the bones of rhinoceros, felis, ursus, fox, and other modern genera are imbedded. In some cases, as at Georgesgmünd, the bones of extinct genera (palæotherium, anoplotherium, mastodon); and existing genera, as hippopotamus, horse, ox, mustela, fox, are found together, but this is not generally the case.

Several instances are known of remains of land mammalia in marine tertiaries, as might easily be imagined from considering how large a proportion of the materials of these strata has been derived from the waste and detritus of the land, swept into the sea by inundations and rivers.

Bones of the mastodon have been observed in the subapennines of Italy; mastodon, hippopotamus, rhinoceros, lophiodon, horse, deer, hare, &c. in the shelly beds of Touraine; hyæna, rhinoceros, elephant, sus, antelope, in the molasse of Estavayer; castor in the crag of Essex; chloromys, canis, in Volhynia; dichobene, palæotherium, in calcaire grossier of Nanterre and Provens.

From all this it is evident that the history of the terrestrial animals of the tertiary era is embarrassing, and not without great difficulty separated from that of the races of later date.

Their remains are chiefly preserved to us in lakes which may have existed through a long series of geological changes, and received and mixed together the exuvie of animals living at widely different periods. Auvergne, for example, appears to have been dry land before the commencement of the tertiary period, and the various lakes of central France may be expected to contain traces of all the races of quadrupeds, which from the commencement of the tertiary even to historical periods lived on that ancient land. The geological date of many of the purely lacustrine tertiaries is entirely unknown; we may perhaps admit that the ossiferous deposit of Oeningen, from which Mr Murchison's fox was unearthed, is of date somewhat corresponding to the lacustrine beds of Weimar and Gmünd, and the post-tertiary deposit of Market Weighton, and may be sure that they are less removed from our own era than the fresh-water beds of the Parisian basin; we may perceive that palæotheria and other extinct genera of pachydermata belong to the older of the tertiary periods, while the elephant, hippopotamus, and felis were more numerous in later days. But, as far as can be at present known, there is no certain criterion of age to be found in the comparison of the fossil reliquæ of land animals.

Igneous Rocks of the Tertiary Era.—In England and the Parisian deposits, there is no trace of any irruptive igneous rocks of the date of the tertiary strata, though there are many great disruptions. The south of France is equally free from such admixtures among the marine strata between the Cevennes and the Pyrenees; but amid the ancient lacustrine beds of Auvergne volcanic rocks are abundantly effused. In Catalonia, volcanic phenomena on a smaller scale are noticed; the Euganean Hills, near Venice, are a more considerable example of igneous irrup-

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The rocks which are thus referred to the tertiary era are principally trachyte and basalt; augitic and felspathic rocks greatly analogous to, or identical with, products of active volcanos. The appearance presented at the points where the igneous rocks have burst up are such as to leave no doubt that, in all the localities above named, the action was of the same kind as that exerted by an active volcano; the forms and grouping of the hills strengthen the analogy, and we finally must conclude that the igneous action developed over a great part of Europe late in the tertiary period, was in fact volcanic. In some cases, indeed, it is not possible clearly and certainly to separate the products of a modern volcano from those of the eruptions which took place in tertiary periods; as, for example, in Sicily and central France. There is evidence that some of these tertiary volcanos burst forth in the sea, as the Euganean Hills, and spread lava over and amongst the strata then forming; in other cases, as in Velay, the eruptions happened amidst fresh-water lakes while the lacustrine sediments were accumulating. The volcanos of the Cantal appear to have followed the deposition of fresh-water limestones comparable to those of Paris and the Isle of Wight. It is perhaps doubtful whether any of the volcanos of this date broke forth in the midst of large tracts of land where no freshwater lakes existed; the Siebengebirge and other Rheinisch hills of igneous rocks are no exception, for the Rheintal has evidently been once filled with water many hundred feet above its present level, as the löss, the trass, and brown coal of the Eifel sufficiently prove.

The result of the researches of Daubeny and others on the subject of the tertiary igneous products, is to connect them, in a very particular manner, with the history of extinct and active volcanos of later date. In some instances it may be admitted that igneous action, which existed in the tertiary area, has been continued almost to historical times (Auvergne), or even to this day (Etna).

DISTURBANCES OF STRATA DURING AND AFTER THE TERTIARY PERIOD.

No more remarkable dislocations are known in the British islands than those two parallel anticlinal axes which broke up the tertiaries of the south of England. These have been already briefly noticed while speaking of the chalk formation. The northern axis, passing east and west from the Vale of Pewsey to near Folkstone, divides the basins of London and Hampshire, which are, in fact, depressions parallel to this axis, from which the northward slope of the strata under the vales of Thames and the Kennet is extremely rapid, and affects equally the secondary and tertiary strata. It is therefore of posterior date to the last mentioned deposits. The southern axis passes east and west through the middle of the Isle of Wight, and is continued nearly in the same direction through the Isle of Purbeck toward Weymouth, where several great dislocations have been traced by Mr de la Beche and Dr Buckland. The northern slope from this axis is everywhere excessively steep, and, in the western part of the Isle of Wight, the chalk, plastic clays, and sands, and London clay, are absolutely vertical. What adds to the interest of this occurrence in Alum Bay, is the circumstance of the frequent lamination of loose variegated sands and interstratification of

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The geographical features of the south-eastern parts of England depend almost entirely on these great lines of disturbed strata, and we may from this learn to view, without surprise, the greater phenomena of the same kind which have been brought to light by the labours of continental geologists. It appears certain that the Pyrenean chain has undergone elevatory movements since the deposition of some of the tertiary strata; the whole chain of the Alps has certainly been raised since the formation of most or all of the tertiary strata, for it bears upon several of its high crests, and in its mountain valleys, not only secondary, but also tertiary beds, as on the Righi and on the Diablerets according to Brongniart, and in the Valley of Gosau, according to Murchison. Parts of Sicily have also been uplifted, even since the deposition of rocks holding 95 per cent. of existing species, to an elevation of 3000 feet.

Besides those local and violent elevations, it cannot be doubted that the whole surface of Europe has been raised to various degrees by more gradual action, since the time of the formation of the marine tertiaries which fill the valleys of the Danube and the Rhine, the secluded basins of Bohemia and Hungary, and the great plains of northern Germany, Poland, and Russia.

The precise (geological) date of these elevations, whether violent or gradual, is one of the most difficult of geological problems; but it is certain that some happened during, and most of them subsequently to, the accumulation of the marine strata of the tertiary period. The general effect was therefore clearly to augment continually the dry land surface of Europe; to establish the various relations of fresh-water drainage at successive times; to permit the accumulation of fresh-water lakes; to allow of the conditions whereto the life of terrestrial and fluviatile animals is adjusted, and thus to offer analogies in all respects to the present order of natural causes and events.

RELATION OF TERTIARY TO HISTORICAL PERIODS.

Of all the classes or assemblages of aqueous deposits, that which is the nearest to our own days in point of date is the least exact in its boundaries and characters. While, concerning the older periods, the problem of the condition of the globe was principally confined to considerations relating to the sea, and thus the phenomena could be investigated according to fixed principles, applicable to at least the greater number of strata; the tertiary deposits compel us to enter also upon more complicated researches connected with the land: and, in discussing the history of still later phenomena, all the variations of physical geography assume still higher degrees of importance. The consequence is an amount of local diversity so great as to nearly annihilate all generality of result.

Moreover, the difficulties of this subject are augmented by a circumstance which is likely to become daily more and more influential on geological reasoning;—the want of a principle upon which to define the limit of least antiquity of this group of strata. What, in fact, is meant by supra-

Geology. tertiary deposits? If we substitute for this term modern aqueous products, do we understand it the better? Or, attempting analysis, if we adopt as an equivalent expression the diluvial and alluvial accumulations, how are these to be defined? It is evident that here is a serious embarrassment.

What is meant by tertiary strata? If we should venture to include in this title all really marine deposits posterior to the chalk, even such as were only yesterday raised from the bed of the sea, it would be more intelligible than the methods now followed by geologists. For with the tertiary strata of Europe begins that extreme *analogy* of the specific forms of organic life, that *identity* of generic conformation, which at once announces great and general differences of physical condition between them and the older strata, and equally great resemblances to the present order of things. Such results apply to marine, fresh-water, and terrestrial life; and, as far as yet appears, (but the evidence is very incomplete), nearly in an equal proportion to each.

Moreover, the changes, to judge either by marine or terrestrial animals, which brought the extinction of old, and the creation of new races, were gradual. From the Parisian formations, containing 96 per cent. of extinct marine mollusca, and something like the same proportion of extinct land quadrupeds, to the Sicilian strata, which contain 95 per cent. of existing species of marine shells, and the lacustrine deposits of Oeningen and Weighon, in which the molluscous remains are wholly, and the quadrupedal reliquæ partially, undistinguishable from living types, every intermediate term may be interpolated so as to constitute a real and complete series of monuments of the gradual substitution of one race for another.

Assuming, for the moment, this conclusion of the gradual change from the oldest tertiary to the actual phenomena of nature, supposing that all the organic and inorganic phenomena produced in the interval from the date of the cretaceous deposits to the present era, may be ranked in one great system, like those adopted for earlier periods, where shall we place the point of union between the modern or historical and the ancient or geological scales of time? In other words, To what part of the supracretaceous period shall we refer the creation of man?

To this important question impartiality must allow that geology gives no clear and certain answer. Geology has no evidence on the subject that is at all of a positive character. We believe that the older stratified rocks were preadamitic for four reasons; because no trace of man or his works have ever been seen in them; because no remains of animals and plants occur in them which can be considered the same or very similar to the existing forms of life; because land quadrupeds generally are almost utterly unknown in them; because the physical conditions of the globe were entirely different from what we now behold.

Let us apply these tests to the supracretaceous deposits. In none of those which have been formed in the sea have we yet found the remains of man or his works; but remains of animals and plants, identical or very similar to existing kinds, are found even in the oldest of them; land quadrupeds occur both in fresh-water and marine strata which are among the earliest *eocene* tertiary deposits; and, finally, the physical conditions of the globe were, at the beginning of the period, very similar to the present, and this similarity continually augmented.

It is evident that all the probabilities point to the conclusion, that the creation of man, and all the new arrangements connected with that event, are to be placed in some part of the supracretaceous period; but in what part, is to be determined by further and cautious research. We cannot undertake to decide so important a problem upon the mere negative evidence of the *absence of human remains* from tertiary deposits, because such negative applies only

to the European and North American tertiaries, none other being explored. Moreover, the deposition of human remains in marine tertiaries must be supposed to have been extremely rare and exceptional cases; nor could they be expected to occur often even in lacustrine or fluviatile deposits. But, as before observed, this negation, however important, is yet only a local truth; human remains may yet be found in tertiary strata in other parts of the globe; nor would it excite surprise if, among 95 per cent. of existing species of marine mollusca in the Sicilian tertiaries, human bones should once be met with. Or if never in European regions this result should arrive, who is to assure us that, in countries more early peopled than these "far western isles," neither lakes nor estuaries of the tertiary era received and preserved some remains of man, or traces of his works?

As far as direct observation or satisfactory inference goes, every honest geologist will allow that he is ignorant of the point of union between the historical and geological scales of time: that the era of human existence, if recorded in geological monuments, has not yet been discovered among the small number which have been fully decyphered.

But, where certainty cannot be had, it is right to enquire into probabilities. It seems fair to admit, both with reference to historical testimony and sound views of the economy of creation, that the existence, in any country, of a considerable number of the animals which now contribute to the comforts and necessities of the human race, is evidence of the establishment, in that country, of the conditions within which Providence has restricted the existence of man. No created terrestrial being is capable, by natural constitution, of sustaining such variety of external physical conditions as man can brave through the exertion of those divine faculties which lift him above the inferior tribes of creation; if, then, the bones of the horse, the ox, the deer, the dog,—of hares, rabbits, beavers, foxes, and other characteristic animals of the present creation, are found in lacustrine tertiaries, what is to prevent our receiving, as the *most probable indirect inference*, that the era of the creation of man had arrived when these strata were accumulated?

Let us adopt this inference though it be indirect, and, without further refinement, which the state of ignorance in which we really are forbids, let us admit that many of the lacustrine tertiaries are of date posterior to the formation of man and the present general arrangement of the terrestrial creation. We shall then class these and a variety of later marine and fluviatile deposits which have many characters in common, as **SUPERFICIAL AQUEOUS DEPOSITS** of the most *modern geological period*, and consider them in relation to many contemporaneous products of subterranean heat.

SUPERFICIAL AQUEOUS DEPOSITS.

Resolved to conform, as much as truth permits, to the present views of geologists, from a conviction that they need rather a cautious limitation, than any essential change,—we shall adopt the following simple classification, suited to the condition of the land and sea in the modern geological period.

1. Marine deposits, . . . (a) raised from the sea, or
(b) yet in progress;
2. Detrital deposits, including (a) Erratic block group;
(b) Ossiferous group;
(c) Ossiferous caves and breccia;

3. Fluviatile and lacustrine deposits, terminated, or yet in progress;—and in each case endeavour to bring forward the history of the phenomena to the present date.

1. a. *Elevated Marine Deposits.*

Whether the Sicilian tertiary strata, containing 95 per cent. of existing species of testacea, should be ranked in this period, may perhaps be doubtful; but they furnish at least a point of departure, and shew us, on a great scale, the magnitude of effects produced by elevatory volcanic action. Just as these, and, in older times, the other tertiaries of the Mediterranean shores, were uplifted, and thus the ancient seabed was laid dry for man's examination; so we find, along the shores of the Baltic, the west coast of Scandinavia, the east and west coasts of Scotland and England, the south coast of England, the west coast of France, and the east coast of Ireland, as well as on the coasts of North and South America, proof of the partial rising of the land and neighbouring bed of the sea once, or several times.

Brongniart (*Tableau des Terrains*, 1829) has the merit of calling the attention of geologists to this phenomenon of local elevation of the bed of the sea. He gives a clear summary of the facts noticed at a great number of interesting points; and attributes the effects observed to a general lowering of the oceanic waters, which he supposes to have been the last of the great geological phenomena which have modified generally the relations of the outline and height of the lands to the area and level of the sea. In conformity with this conclusion, he carries back the date of such elevations beyond the historical era,—remarking that no trace of human reliquiae occur among the gravel and shells of those elevated tracts.

The real date of many or most of these elevations must be allowed to be unknown; but the cause assigned by M. Brongniart is inadmissible, being contrary to physical probabilities, and inadequate to the explanation of the particular phenomena.

English Shores.—One of the most remarkable examples is that observed by Mr William Gilbertson of Preston, on the coast of Lancashire, of which Mr Murchison gave the following notice at the York Meeting of the British Association. “The deposit consists, near the surface, of clay with bouldered rocks, covering great thickness of marl, gravel, and sand, the sand being usually the lowest. These accumulations are not only spread over the broad delta extending from the coast at Blackpool to Preston in the interior; but they rise at the latter place into considerable eminences, extending in plateaus on the banks of the Ribble and the Derwent for several miles inland. In certain places the marls, sands, and gravels contain shells of existing species (Mr Gilbertson enumerates above twenty species), not differing from those of the adjacent sea, above which they were found at various heights from 80 to 300 feet. The accumulations seldom offer proofs of regular bedding or tranquil deposit, but rather resemble the detritus found upon an agitated shore; although, in their diversity of structure, they present distinct evidence of having been heaped up during a long protracted period.” (Among the shells we have seen *Turritella terebra*, *Cardium edule*, &c.)

Sir Philip Egerton has lately found a bed of gravel containing marine shells of recent species, at the Willington, in Cheshire, at the base of the “Forest Hills,” seventy or eighty feet above the Mersey. This bed of ferruginous gravel and pebbles, *unlike the usual gravel of Cheshire*, was found to contain *Turritella terebra*, *Cardium edule*, *Murex erinaceus*, and others. *Over this shelly bed* was the ordinary sandy diluvium of Cheshire, full of boulders of many rocks.

Mr Trimmer found marine shells (*Cardium*, *Turritella*, and *Buccinum*) in the sand and clay at Runcorn, several feet above the level of the tide, and under a deposit of peat, which was covered by sand and gravel.

Near Shrewsbury, Mr Trimmer has noticed marine shells of existing species (*Turritella terebra*, *Cardium edule*, *Tel-*

lina solidula, &c.) in transported gravel and sand, resting on a peat-bog, which contains imbedded trees (oak, beech, and fir), and rests on gravel. On both sides of the Severn, near Shrewsbury, he found fragments of marine shells.

From these and other data, Mr Murchison has been led to entertain the opinion of the elevation of the whole line of country from Lancashire through Cheshire to Shropshire and the vale of the Severn, as of very recent date, compared to many other geological phenomena. (*Geol. Proceedings*.)

Mr Trimmer also collected from the summit of Moel Tryfan, near Caernarvon, 1000 feet above the sea, marine shells “diluvial” sands and gravel. The shells were fragmentary, had lost their gelatine, and consisted of *Buccinum*, *Venus*, *Natica*, and *Turbo*. The subjacent rocks are worn and scratched by friction of the transported pebbles.

On the east coast of the island, we have, in the valley of the Forth (according to Boué, Maclaren, &c.), terraces at some height above the water, containing *Ostrea edulis*, *Mytilus edulis*, *Cardium edule*, *Turbo littoreus*, *Patella vulgaris*, *Donax truncatulus*, and other littoral shells. Similar facts are noticed on the Clyde by Captain Laskey; on Loch Lomond by Adamson. On the Yorkshire coast, an excellent example of this kind of elevation of the bed of the sea has been found on the lower part of the clay cliffs of Speeton. The yellow sandy beds here occurring have much the aspect of a really tertiary stratum, and contain *Cardium edule*, *Tellina solidula*, *Amphidema depressum*, in extreme perfection, without the least mark of violent agitation, either on the shells or on the deposit.

Farther south, the shelly gravel described in the *Geology of Yorkshire*, vol. i. as occurring in the southern part of Holderness, at Ridgmont, and Paul, though its irregularity of deposition seems to point to some difference of origin—to diluvial currents, rather than a mere elevation of a beach,—will complete our view of the subject. These sandy and gravelly beds rise to twenty or forty feet above the tide, and in their contorted and violently confused layers, among pebbles of all the northern and western rocks of Yorkshire and Cumberland, lie the strong shells of *Turbo littoreus*, *Purpura lapillus*, and *Buccinum undatum*,—the thin *Mya arenaria*, *Tellina solidula*, *Tellina tenuis*, and *Mactra subtruncata*, all recent shells of the German Ocean, and with them is an extinct shell. This shelly gravel passes under a deposit of peat and alluvial sediment.

Marine shells also occur in the gravel of Holme, on Spalding Moor, far inland, and a hundred feet above the sea.

Norway and Sweden offer considerable examples of these uplifted shelly littoral deposits. At Figa-elv, in the northern part of Norway, according to Ström, broken shells occur more than 150 metres (490 feet) above the sea. At Suroë and Tromsø, further south, they occur a few metres above the sea: also near Drontheim.

M. Brongniart describes minutely the shelly deposits of Uddevalla, in the province of Gotheburg, on the west coast of Sweden. Here, in a little bay bordered with rocks of gneiss, great quantities of shells occur nearly in a perfect condition, 70 metres above the sea (230 feet). The shells are those of the neighbouring sea. And to shew how truly the phenomenon indicates a relative change of level of land and water, M. Brongniart found *Balani* still adhering to the gneiss rock; proving the spot on which the testaceous animals are found to have been really the littoral bed of the sea.

The whole subject of the elevated beds of marine shells in Scandinavia has lately been investigated by Mr Lyell, who finds them near Stockholm, 30 feet, 70 feet, and 100 feet above the sea, in sand and gravel, or in marl resting on gneiss. In one place a *fishing hut* was found under 64 feet of shelly violet-coloured marls. The shells observed in the different localities were all residents of the Baltic, viz. *Cardium edule*, *Tellina baltica*, *Mytilus edulis*, *Lit-*

Geology. rina crassior, Littorina littorea, Paludina ulvæ, Neritina fluviatilis (which lives in the Baltic). A land-shell, Bulimus lubricus, was also found. Near Upsala, thick clays, which lie over the gneiss and granite, contain Tellina baltica, Mytilus edulis, a small flustra and fuci, 60 to 80 feet above the sea. In a ridge of sand and gravel, a violet-coloured marl-bed, 80 feet above the sea, yielded Mytilus edulis, Cardium edule, Tellina baltica, Littorina littorea, Paludina ulvæ?

On visiting Uddevalla, the adherence of Balani was noticed in a new situation, with cellepora;—the quantity of shells lying in stratified clays, sand, and gravel, reminded Mr Lyell of Parisian tertiaries. Twenty-seven species of mollusca, and one echinus, were collected in a day. Among these are four zoophagous mollusca, not met with on the Swedish side, nor now existing in the Baltic, but found in the open sea. At several other ports on the western coast near Gothenburg, marine shells, in beds of clay, and sand, and gravel, were found at different heights above the sea. They also occur fifty miles from the coast, west of Lake Wener. Thus it is evident that the bounds of the ocean have here been greatly contracted since the present species of testacea began to inhabit the Baltic and the neighbouring parts of the German Ocean. (*Phil. Trans.*)

Near St Michel en Lhermes (Charente inferieure et La Vendee), are three hills, situated six kilometres (about $1\frac{1}{4}$ mile) from the sea, about 1000 feet long, and their top 15 metres (50 feet) above the level of the highest tides. These hills are wholly composed of marine shells, solid in texture, with their colour preserved, and valves generally united, so as to indicate tranquil residence in the sea.

Near Nice, Risso has noticed perfectly preserved marine shells, in calcareous sand, 57 metres above the sea (150 feet.)

Near Maïta, in the Peninsula, between the Hellespont and the Gulf of Saros, Olivier reports marine shells in the friable grit: and the same are seen beyond the hill of Abydos.

According to M. Hertzog, as quoted by M. Brongniart, similar accumulations are seen near False Bay, Cape of Good Hope, 66 metres above the sea.

At Guadaloupe, St Domingo, on the coast of North America, on the western coast of South America, in the Red Sea, in Timor, and on the north-east coast of Iceland, the same phenomena occur,—the shells in all cases resembling those of the adjacent seas.

As far as regards the elevation of these shelly beds above the sea, either a gradual rising, or a sudden uplifting, will equally explain the greater number of cases; some may suit with the one, and some with the other explanation. But the most important thing to remark is, that the shells have not been laid in their present situation by any sudden violence of water. Generally the great masses of diluvium, and the large and far-travelled boulders, which are supposed to indicate cataclysmal movements, *lie upon such shelly beds.*

In a few instances it may be reasonable to attribute the accumulation of the shells to currents set in motion by local convulsions. We should prefer this view for the phenomena of the southern part of Yorkshire, near Hedon, but are *sure*, on the contrary, that the Speeton sand-bed was formed under the sea; and adopt the same view for the phenomena in Sweden and Norway, the coast of Lancashire, the interior of Cheshire, the valleys of the Forth and Clyde, and indeed generally.

Who would have imagined, before Von Buch's and Brongniart's researches in Uddevalla, and Lyell's journey to other parts of Scandinavia, that so considerable a part of the coasts of the present islands and continents should be proved to have been the gift of subterranean movements, since the present race of marine animals were called into

being? Yet, now that it is known, who does not perceive, in these modern phenomena, the consequence of the same causes as those to which geologists have long appealed for explaining the elevation of older sea-beaches,—like the English crag or submarine sediments, like the subapennine or Sicilian strata? Further, the inquiries of Mr Lyell in Scandinavia, as to the elevation of the coasts of that peninsula (*Phil. Trans.* 1835), go far to prove that the elevatory process is there still, however slowly, in action. However the yet disputed point of the uprising of the Chilian coast in 1822 may be settled, it is undoubted that many such risings, to a greater extent, have happened in those parts. The recent personal investigations of Mr Darwin have shewn that large tracts in Patagonia are nothing else than a sea-bed, raised in modern times, that is, since the creation of the present races of marine mollusca; and that strata of corresponding age form part of the double Cordilleras of the southern part of America. Thus, we are entitled to admit, among the effects of existing causes, *partial vertical movements* of the land.

b. Submarine Deposits still in progress.

Much of what goes on in the sea is entirely unknown to us. In fact it is only along the shores, at the mouths of rivers, and in shallow gulfs and seas, that we have any positive measures of the changes which take place in the bed of the mysterious deep. Nor have we yet obtained from the sounding line so much, or so exact instruction as nautical experience might furnish. How far into the sea currents of given velocity may transport sedimentary grains of given magnitude and specific gravity, is matter of calculation (Babbage); how far, in fact, the supernatant fresh waters can carry their earthy admixture, has been, in one instance, ascertained (River Amazons, Captain Sabine); thus we learn that sedimentary strata are really forming, with great regularity, over great spaces of the ocean bed; and this knowledge is of high theoretical value. But still it is to the shores that we must ever turn for data to serve as bases for comparison between modern and ancient marine deposits.

Here we see that the materials which the sea obtains from the wasting cliffs, rivers, and floods, are partly transported away by currents, and especially during storms, to considerable distances, but principally drifted coastwards, and deposited in times of tranquillity, or in retired situations, especially where the land is low and protected by far sloping banks, so as to augment incessantly the area of the low marshy tracts at the expense of the higher ground. In distributing the materials which fall from the cliffs, the agitation of the sea produces an effect of the same kind as the operation of washing a mixture of metallic ores and various spars; it separates the ingredients according to magnitude and specific weight,—the heavy and large masses are left on the beach for slow distribution over the sloping surface or gradual descent into the deep,—the coarse sand is urged onward by the tide, as a river pushes forward its bed, but the finer clays mix with the water, remain long suspended, and are carried to great distances, to be deposited wherever the sea stagnates, either by expansion over level surfaces, or opposition of the freshes.

It is evident that the modern deposits of the sea are pebbly where the agitation is great, sandy where it is moderate, and argillaceous where it is little.

In general, the deep sea deposits (exceptions may be necessary where currents of great force prevail in shallow seas like the German Ocean) must be of finer grain than those near the shore. The surfaces of contemporaneous deposition are slopes rising every where toward the shore, where alone they become, for a very short distance, steep.

What becomes of the calcareous matter swept down to the sea is not fully known. The formation of durable coralline and molluscan exuviae from the sea will account for the

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Geology. consumption of much of this earth ; and, in particular cases, Mr Lyell's remark of the formation of calcareous beds at the mouth of the Rhone will apply. But chemistry has not yet determined the *statical* composition of the sea, and, of course, it is utterly unknown what *variations* volcanic eruptions, gaseous emanations, changing temperature, unequal pressure, and other causes, may occasion. Dredgings, soundings, and the experience of fishermen and divers in the German Ocean, Adriatic, and English Channel, inform us of the distribution of living zoophyta, mollusca, fishes, and crustacea, and of the parts of their decayed bodies. Certain tribes of mollusca, like the oyster, the coral, the mussel, inhabit limited breadths of the argillaceous, sandy, or rocky shores and shallows. Crustacea, pleuronectida, and other fishes, have their certain localities. The teeth of some fishes are noticed as being loose in the bed of the sea. The growth of the Coral Islands, if it be generally like that of the Bermudas, as described by Lieutenant Neilson (*Geological Proceedings*), offers greater analogies than might have been expected to the ancient zoophytic limestones, not only in the mass of matter, but in the irregular and partial distribution of the polyparia, the admixture of earthy and compact carbonate of lime, inclusion of shells, and partial stratification.

Could we raise, for inspection, the shallow German Ocean, the unequal depths of the Mediterranean, the Gulf of Mexico, or the base of some volcanic group of the southern ocean, what variety would meet our eyes ! shelly deposits, coralloidal limestones, volcanic sediments, submarine lavas, strata of red and variously coloured clays and lignites,—almost nothing in common ; contemporaneous difference carried to extreme ; local diversity, overcoming all general agreement. Yet all the parts of this picture can be paralleled in the older marine deposits,—the only difference being a greater analogy of the contemporaneous effects,—a more decided and real relation of the phenomena to time ; proof of the sequence of effects being due to successive general changes of physical condition,—these changes continually altering the original aspect of nature, continually tending to diversify the uniformity and complicate the simplicity of the primeval state of the globe. Thus irregularity of surface, diversity of local phenomena, deviations of temperature, had always gone on augmenting till the globe assumed that inexhaustible variety of external conditions which harmonizes with its present rich adornment of vegetable and animal life, and continually excites and rewards the curiosity of the wonderful being who was placed by his Maker at the head of his last living creation.

2. DETRITAL DEPOSITS.

a. *Erratic Block Group.*

Since the time when the whole stratified crust of the globe was supposed to have subsided from a universal flood of water, the geological effects ascribed to the historical deluge, and other violent agitations of water, have continually diminished. It is not many years since we were familiar with the doctrine of the excavation of valleys and the accumulation of detritus over large surfaces of the globe being due to diluvial action ; and now a large class of geologists, with Mr Greenough at their head, declare themselves incapable of distinguishing between the traces of such a deluge and the effects of more modern and local disturbances. There are geologists who would gladly expunge the word diluvial from our nomenclature, and instead of appealing to one or several general convulsions for the explanation of some striking fact, are willing to believe that small and local forces, operating through long time, are sufficient for the purpose of geological speculation.

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Such a case, it has been long supposed, was furnished by the examination of the dispersion of great blocks of the high Alps over Switzerland, and through the passages of the Jura into France ; another example was found in the drifted sienites and limestones of Sweden, which lie in Northern Germany ; a third in the transported masses from the Cumbrian mountains ; a fourth in Canada.

The erratic blocks, as the larger boulders are called, which have been transported from the Alps, are most remarkable on the eastern face of the Jura, which looks towards the Alps, over the vale of the Arve and the Lake of Geneva. On the Jura, 1500 to 2000 feet above the Lake of Geneva, crowning the hills and filling the valleys and rocky glens ; in and around the Lake of Geneva and the valley of the Arve, as well as along the valleys which descend from the Alps, these blocks abound. It is observed that the blocks abound opposite to the embouchures of these valleys, and that distinct sets of blocks, derived from different mountains, have followed the lines of the different valleys. The blocks in the valley of the Rhine have come from the Grisons ; those by the Lake of Zurich and the course of the Limmat were drifted from Glaris ; blocks from the source of the Reuss have followed this river ; the blocks of the Aar, and the slopes of the neighbouring Jura, have come from the ranges of the Oberland of Berne. From these facts, and the circumstance that the height to which the blocks have ascended the Jura is greatest opposite the valleys which descend from the Alps, no doubt can be entertained that the currents flowed from these mountains in many directions, and followed the line of the present valleys.

It appears the most probable view of these phenomena, that a general and violent convulsion of the Alps, while they were surrounded by water (whether fresh or salt we cannot decide), caused powerful currents to rush away from the axis of movement, bearing ice-rafts loaded with the loosened rocks. Thus might large boulders of particular rocks be accumulated in groups, as we find them on the Salève near Geneva, and in various parts of the Jura, or distributed in single masses over the vale of the Aar and the Lake of Geneva, then full of water, by the damming of the Rhine at Basle, and the Rhone at Fort d'Ecluse. Thus it seems conceivable that, in the agitation of the movement of water, some rocks might find their way through the openings of the Jura into the plains of France.

This explanation appeared satisfactory to Venturi, reasoning on the phenomena of the south side of the Alps. It has been suggested from the case of the blocks on the drainage of the St Lawrence, and is proposed as the most probable view of the facts observed concerning the multitudes of rock masses which have crossed the Baltic, and dropped in heaps on the plains of Northern Germany, Po-

Geology. land, and Russia, from the Ems and the Weser, to the Dwina and even the Neva. These blocks are grouped in narrow elliptical areas, with the longer axis pointing north and south, or toward the Baltic; they often lie on the surface, especially the larger blocks, hardly ever at great depths. They consist principally of granite, sienite, porphyry, and transition limestones, with characteristic fossils which can be exactly paralleled in the southern parts of Sweden, and nowhere else. On crossing from Zealand to Scania, the traces of blocks reappear. The surface of Scania is covered with them; and farther north they abound in elongated hills called "Oasar" (analogous to the word "escarp" in Ireland), ranging north-north-east to south-south-west. The blocks are more numerous on the Swedish side of the Baltic, nearer their origin, but not larger. Worn and polished surfaces among the primary rocks of Sweden are attributed to the transport of heavy bodies.

The dispersion of blocks from the Cumbrian group of mountains is extremely remarkable; and the example is more valuable to geology than most others of this nature, from the exactness with which the circumstances are ascertained. There are also peculiar relations of the tracks followed by the blocks to the ancient physical features of the country.

In the Cumbrian mountain group, the granites, sienites, porphyries, and metamorphic slates, are more or less peculiar in character, and easily recognisable. The granite of Ravenglass, on the western border of this region, has been drifted to the south, across the sea, along the flat or hollow of Lancashire west of the Penine chain, and over the plains of Cheshire and Shropshire, toward the vale of the Severn. In this long course, the quantity of pebbles and boulders of the Cumbrian rocks is considerable; and it is evident, that the currents, whatever they were, which carried the boulders, respected the present levels of the country, so far as never once to cross the Penine chain to the eastward, nor to penetrate far into the principality or the border districts, where, Mr Murchison assures us, the gravelly deposits are all derived from the neighbouring hills. From the eastern side of the Cumbrian mountains the porphyritic granite of Shap Fell, and the sienite of Carrock Fell, have been transported northward to Carlisle, southward by Kendal and Kirby Lonsdale, to beyond Lancaster, eastward over the vale of Eden, and up the Penine escarpment at Stainmoor, above Brough. Having here mounted the summit, the boulders diverge to the east by north, east and south-east, cross many lower ridges, traverse and descend the vales of York and Cleveland, and sweep over the oolitic moors and the chalk wolds to the sea-side at Scarborough and Flamborough-Head, a distance of 110 miles. In this passage three ridges of anciently elevated land, and two deep geologically ancient vales, were crossed: yet the water so far respected the elevations of ground now existing, as not to cross the Penine chain at more than one, and that *the lowest point opening directly to the west*, and to avoid the highest part of the oolitic moors. What renders this more curious and complete is the circumstance, that one of the valleys crossed (the vale of Eden), 1000 feet below the origin of the granite, and 1000 feet below Stainmoor, is a valley caused by dislocation of the carboniferous system *prior to the new red sandstone era*, and the date of the dispersion of the blocks is since the newest tertiaries in the north of England.

If, however, following the indications of the phenomena, we refer, in every case, the dispersion of the blocks to the uplifting of particular mountain groups, and this is almost a certain inference, we may perhaps admit, in the neighbourhood of such groups, temporary variations, or *undulations* of the land, like those which accompany earthquakes, sufficiently extensive, when combined with the agitation of

Geology. the sea, to permit the water to take, for a short period, directions previously and subsequently impossible. That the whole was the effect of a very short period, is the universal impression of all observers.

It is evident from all that has been proved, inferred, and admitted on the subject of the *erratic blocks*, that they were derived from particular mountain groups, drifted thence to limited, though considerable distances, along lines which respect the present levels of the country, both as to height and direction. They lie generally at the surface of the superficial marine diluvium, and speak plainly of great and violent convulsions. Yet it is already certain that they are monuments of merely local however violent disturbance, not proofs of universal or even very great or general floods.

From each mountain group, the blocks have gone in directions corresponding with its slopes and the configuration of the neighbouring country. Many local centres of subterranean movement may thus have simultaneously or successively thrown off their rocky fragments; some of these, with other materials, were washed by the waves over surfaces momentarily changed in level by the concussion, others drifted on icebergs to great distances and quietly dropped on the surface. The phenomena, then, are merely a continuation of those which have been proved to occur in older times, with this difference, that *they* were for the most part performed in the sea, which reduced the products to a stratified form; *these* irregularly accumulated on the land.

Nothing in modern times so nearly approaches these effects, as the iceberg detached from glacier-covered shores in Arctic regions, floated hundreds of miles by oceanic currents, and dropping its load of rocks and detritus in distant regions. Could we witness the elevation of the bed of the northern ocean, would it not shew a group of detritus somewhat analogous to that of the erratic blocks; might we farther suppose the ice-borne detritus to be forcibly thrown over the land, would not the resemblance be perfect?

b. Ossiferous Gravel, Clay, &c.

Since the publication of Dr Buckland's valuable work, the "*Reliquiæ Diluvianæ*," and Cuvier's magnificent volumes, entitled "*Ossemens Fossils*," the attention of zoologists and geologists has been in an especial degree attracted to the superficial deposits containing bones of quadrupeds mostly extinct, and belonging to genera often no longer met with but in far distant regions.

These quadrupedal remains are found in gravel and clay, in caverns, and fissures, under various circumstances indicating different mechanical and vital conditions, though still, by many geologists, ranked with erratic blocks under the one general and vague title of "*diluvial deposits*." This is certainly inexact, yet it is not to be thought that the arrangement has been founded on no real analogy; on the contrary, all that is yet known appears to shew that what have been called diluvial deposits, however different in origin, have all the common bond which in geology is most important, viz. time. For throughout all these deposits, the quadrupedal remains have a general uniformity of character, and a common degree of difference from the existing races of animals, which points to high antiquity, but not to the remote eras of the early tertiary deposits. Even a brief history of the discoveries in this field of research would fill a volume—even a mere selection of remarkable phenomena would occupy great space. The following notices are confined as much as possible to a short view of the principal results already obtained.

Ossiferous superficial deposits abound in Europe, Asia, and America; even far toward the polar circles (both in Asia and America). They consist of clay, gravel, sand, peat, marl, &c. sometimes accompanied by marine or fresh-water

Geology. shells. Some of these are of comparatively modern date, and contain bones of existing races of animals; others belong to ancient times, and contain the remains of extinct tribes. It is to these latter that the name of diluvial deposits properly belongs; and though it is to be supposed that there are ossiferous accumulations of every age intermediate between the diluvial and modern periods, yet in many cases the following considerations will enable a geologist to pronounce whether a particular deposit falls within the proper meaning of the term diluvial.

There is no sufficient reason to class an ossiferous deposit of Europe as of the diluvial era, if its accumulation can be explained by the action of existing streams. But if amidst the mass of materials which it contains are fragments of rocks brought from other regions, in directions irreconcilable with the actual courses of streams, or any other courses of streams consistent with geological probability; if the quantity and mode of aggregation of these materials imply the violent and tumultuous movement of considerable bodies of water; and if the bones belong wholly or principally to extinct species of animals; more particularly, if bones of extinct species of elephant, rhinoceros, and hippopotamus occur, then it is most probable that the deposit may be rightly classed with diluvial accumulations.

In some cases, it is true, no certainty can be obtained whether the accumulation took place in the sea or on the land; whether the deposit is a raised beach, or a tumultuous accumulation on the land. Occasionally there is no distinction between gravel beds and erratic blocks; sometimes alluvial and diluvial formations are inseparably mixed; yet in many instances all these uncertainties vanish, and we are sure that we behold the accumulations from great floods which passed over limited ranges of the dried and inhabited land.

In the valleys of the Tyne, Wear, and Tees, the vales of York and Cleveland, the district of Holderness, the eastern counties, Norfolk, Suffolk, Essex, the vale of the Thames, the valley of the Trent, and the counties of Lincoln, Huntingdon, Cambridge, Northampton, Warwick, Stafford, Chester, Lancashire, not to mention many others, gravel of the diluvial character, often containing bones of extinct mammalia, abounds. In Ireland, in various parts of France, Switzerland, Italy, and Germany, similar facts have been observed. In North and South America geologists have recorded the same experience.

In many instances the same districts yield lacustrine sediments, and peat deposits, so related to the ossiferous clays and gravel by position and organic contents, that they must be ranked as of the same age; frequently, also, we find in the limestones of the same regions, caves and fissures full of bones of the same extinct animals, and so circumstanced as to permit of their being added to the others as animals of a particular era. The most frequent of all these remains in England, and several parts of Europe and Asia, are the bones of fossil elephants; and from this circumstance we may name the geological period of their existence, in polar regions, the elephantoidal period, in contradistinction to the older or palæotherian period; it being always understood that these terms apply only to the land, and that we have good reason for doubt as to the practicability of referring the period which they designate to the general geological scale, depending on the succession of marine strata.

In consequence of the variety and celebrity of the ossiferous districts surrounding Kirkdale Cave in Yorkshire, we shall take this as an example of the deposits of the elephantoidal period in England.

The diluvial accumulations of Holderness, like all those of the eastern side of the north of England, consist partly of clay, partly of gravel and sand, all more or less mixed with fragments of rocks from different quarters. The clay

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Above it and also below it, are gravels and sands far less replete with those proofs of wide and devastating waters, but sometimes more productive of bones and marine shells. Thus there is proof in this country of successive and different actions of unequally violent water flowing in various directions, with no regard to the lines of existing valleys or rivers, but with so much of a general reference to physical geography, as to have accumulated detritus in the great plains and broad vales more plentifully than on the hills.

This may be taken as a type of such phenomena in England and Ireland, where the detrital deposits are very extensive, and Scotland, which exhibits less of them.

Without attempting to trace the details of detrital deposits on the continent of Europe, we may observe that they are very extensive, yet not so general as was imagined (See *Reliquiæ Diluvianæ*). Certain districts, as for example the volcanic tracts of central France, shew nothing of the kind; others, as Normandy, the basin of Paris, the hills on the borders of the Rhine valley, the valley of the Rhine, large tracts in northern Germany, in Italy, display similar phenomena to those in England. In every region it is found more or less easy to point out the direction of the diluvial waters concerned, and the result is a growing conviction that not one general, but many partial deluges rushing from particular centres, have occasioned the complicated accumulations.

In the eastern part of North America, Professor Rogers and Dr Bigsby agree in ascribing to the floods which have caused the boulders and gravel beds, a northward and northwestward origin. This is the most general result—combining, however, many different directions from different local centres—for Ireland, Scotland, and England. The Scandinavian rocks have gone south, south-east, and south-west; the Alpine boulders in all directions from the central axis.

In the north of Asia, and perhaps also the north-west of America, if we were to judge from the vast quantity of elephantine bones on the banks of the northern seas, the diluvial currents were towards the north; and it may hereafter appear possible to unite all these facts into one general conception—of the effects of an oceanic current, which may have been the resultant of many local disturbances, directed along opposite meridians and passing over the north pole; northward, up the Pacific and over eastern Asia; southward down the Atlantic, and over the west of Europe, and the eastern part of North America.

c. Ossiferous Caves and Fissures.

The preceding observations have established the facts of the land now existing as such in the northern zone of the globe, being inhabited by extinct races of quadrupeds, during the detrital, diluvial, or clysmic periods of geological time. It is therefore in no degree singular that we should find in caves and fissures of the rocks in these same districts, additional proofs of such occupation, and addi-

Geology. tional facts to complete our views of the then condition of the surface of the land. Through the researches ably prosecuted by Dr Buckland, and continued to the present day, the history of these remarkable repositories of the bones of the early land inhabitants of the northern zones is in a great degree known. It is certain, from these inquiries, that a great change has taken place in the quadrupedal inhabitants of Europe, northern Asia, North and South America, and Australia, apparently coinciding with the era or close of the period of detrital land deposits; for it is remarkable that the bones of extinct mammalia are almost unknown, while those of existing races are frequent, in deposits of more recent date.

The number of species of animals found enclosed in these natural rocky sepulchres is often greater than in the most prolific gravel deposits. It appears that the same cave has been resorted to both by extinct and existing races of quadrupeds, their bones being often situated so as to demonstrate that the former were entombed before or during the detrital era, the latter introduced at later periods. But often this distinction is imaginary, and no doubt can reasonably be entertained of the contemporaneous sepulture of certain extinct races, and some living species of quadrupeds. In fact, ossiferous caves are of various ages, and some were filled with bones in very modern times.

The bones of man, and traces of his ingenuity and labour, have been in several instances observed; generally under such circumstances as to indicate clearly their introduction since the elephantoidal era; but in a few instances it requires something more than the direct evidence of the senses to be satisfied of this difference of date.

The distinction of ossiferous caves and fissures is sometimes real, often imaginary, and never of great importance in reasoning on the phenomena. Fissures are often denuded caves; caves are often but enclosed fissures. They are almost absolutely confined to calcareous rocks, vary wonderfully in size, shape, and detailed circumstances, and contain the same or different groups of animals, even in a small district. The condition of the bones in them is extremely various, and the inferences from all the known facts point to great diversity in the circumstances by which they have been introduced. The formation of the caves is generally not to be explained except by supposing original cavities, or superinduced fissures, to have undergone enlargement by the chemical action of acidulated water. In many cases water still flows through similar caves; in several ossiferous caverns and fissures, sediments and deposits are found which prove the former passage or percolation of water, though at present the subterranean drainage takes another course.

A very considerable proportion of the ossiferous caves yet known has been discovered on the banks of streams, or in cliffs against the sea; in some instances (Franconia, Kirkdale), the openings of caves known to have served as dens appear in situations so difficult of access, as to render it probable that the surface of the ground has been considerably worn away since the cave was occupied.

These ossiferous repositories have been found in the north and south of England, in limestone of different antiquity, as oolite and mountain limestone; in Belgium, the south and south-east of France, in Franconia, Westphalia, Carniola, Hungary, along the margin of the Mediterranean, in North and South America, and Australia.

It is to be inferred from the various investigations of the condition and circumstances of these deposits, that the bones have been received into the caves and fissures in one of three modes.

1st, Some of the caves were occupied as dens during long periods, by ferocious and predacious beasts; as hyænas in England, bears in Germany.

2d, Into other caves and fissures quadrupedal reliquiae were drifted by water.

3d, Some caves, communicating to the surface, appear to have received merely the bodies of quadrupeds which fell into them, or their bones moved from slight distances.

It will be sufficient to notice a characteristic example of each, and refer to Cuvier and Buckland for further and full details.

Kirkdale cave, described by Dr Buckland, contained on its long narrow level floor a bed of mud glazed over by stalagmite, and in this mud and in the stalagmite lay multitudes of bones of quadrupeds, especially of ox and hyæna, under such circumstances as left no doubt in the mind of its explorers that it was a den of hyænas, which for a long term of years roamed in the adjacent valleys, and dragged into this hiding-place the bodies of oxen, deer, and many other animals then living in the neighbourhood. The evidence for this opinion is very convincing, but it must be seen in the museums where the remains are preserved, not judged of from descriptions or figures. The broken and mangled state of the bones from this cave is exactly like what was seen in the similar hyæna cave of Kent's Hole, Torquay, but directly contrary to the aspect of those from Banwell in the Mendip Hills, which was not tenanted by these destroyers.

As far as can be known, the bones of this famous cave—those of the marl beds of Weighton, and the diluvial clays of Holderness, are identical. The number of kinds of animals whose remains were found in the cave was twenty-four.

The remarkable cave of Gailenreuth, in Franconia, is a bear cavern, consisting principally of two large chambers varying in breadth from ten to thirty feet, and in height from three to twenty; the roof is hung with stalactite, and in the first chamber the floor nearly covered with magnificent pillars, mammillary masses, and sheets of stalagmite. Under this stalagmite lies a bed of brown loam and pebbles, mixed with angular fragments of rock, and teeth and bones. These latter were far more numerous in the next large cavern, which is on a lower level where the floor has been much broken up. In some lateral ramifications from this chamber, the number of bones imbedded in loam, or encrusted in stalagmite, is wonderful. "The upper part of the existing cave, and probably others which have been cut away by denudation, seem to have been the lodging places of bears that lived and died in them during the period immediately preceding the introduction of the mud and pebbles. The diluvial waters rushing into them, and the other similar caverns of Franconia, would introduce pebbles and mud, and would also drift downwards to their lowest recesses the bones that lay perhaps more equally distributed than at present." Stalagmite has since covered the mingled deposit. (*Reliquiæ Diluvianæ*, p. 136.)

The calcareous cliffs on the Mediterranean shores of Spain, south of France, Nice, Corsica, Sardinia, Dalmatia, &c., abound in caves and fissures, and many of these are filled with a mingled mass of red loam, fragments of rock and bones of land mammalia,—frequently holding land shells,—rarely marine shells and zoophyta (at Villefranche.) Some of the caves have apparently been subjected to the action of the sea before and for some time after the introduction of the bones. (Christie and Pratt on the Cave of San Ciro near Palermo). Dr Christie supposes the breccia of San Ciro to have been deposited in water, and that the whole of the coast has since been uplifted from the sea.

As an example of a cave into which animals appear to have fallen, we may notice that of Banwell in the Mendip Hills (*Ann. des Sc. Nat.* ix.) The descent is made by steps ten feet deep into a small chamber about ten feet wide; from this a passage leads to a second chamber thirty feet broad, forty-five long, ten high. From the entrance into this large cavern, runs a cleft or fissure in a vertical direction to the surface. At the other end of this cavern is an inclined passage forty-five or fifty feet long, and at the en-

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Valley, Fluvial, and Lacustrine Deposits.—A certain class of fluvial, or rather as we should wish to call them 'valley' deposits, have attracted less attention than they merit. In some cases, as in Glen Roy, and certain valleys of Canada, terraces at particular and very elevated levels, range round the sides of the valleys, and mark, apparently, the ancient shores of an inland lake which has since burst its barriers. More frequently, as at the lower end of Glen Roy, and many other Highland valleys, on the Lune and other Cambrian streams, the Tyne, the Tees, the Yore, and almost all the other waters of the north of England, gravel terraces in the lower parts of the valleys, indicate the flowing of voluminous streams at higher levels in the direction of the actual river. This phenomenon, though little noticed, is really one of the most general we are acquainted with, and always bears in a very important degree upon the question of the origin of valleys, and often on the question of relative level of land and sea.

A different set of phenomena has been observed on the Rhine. That long valley in former geological periods had been dammed up at different points (Hibbert), and deposits (called Löss) of alluvial sediment have been formed along the margin of the elevated waters of the lakes thereby occasioned. The löss beds of the Rhine valley contain sand and fresh-water shells, and bones of elephants and rhinoceros (Horner, Lyell). What is called löss in Austria seems to be a similar deposit, and contains elephantine remains, (Murchison).

All the deposits above mentioned are of great antiquity; the löss of the Rhine valley rests, indeed, on the detrital gravel, but it is far removed from the date of the phenomena produced by the actual river Rhine.

The effects of actual rivers in the past and present economy of nature, admit of clear enunciation.

These effects are principally mechanical. In the early part of their course some streams drop carbonate of lime, others acquire it, but these effects are not important. The mechanical action of rivers, whether corroding or transporting, is proportioned to their velocity and volume; these are seldom combined except in particular great rivers like the Indus, the Mississippi, and the Rhine. The velocity is, for short distances, greatest in the upper parts of rivers; but their volume of waters augments toward the sea. Near their origin, rivers are both corroding and transporting agents; as they proceed, the former influence is often lost or compensated by the contrary process of deposition, the latter is weakened in most rivers, destroyed in some, but in a few maintained to the very conflict of the tides and freshes. (Captain Sabine's *Observations on the Sea Current of the Amazons*.) Rivers then, soon after their springs issue from the rock, begin to gather and transport sediment; but it is less by friction on their own beds than by the aid of atmospheric disintegration of rocks, and waste of the surface by rains, frost and glaciers, that they derive the matter which they bear along. According to the velocity of the stream, and the inclination of its bed, is the magnitude of the masses which it can drive forward. Few of the rivers of England, unless their waters be augmented by temporary floods, are swift enough to transport even moderate-sized gravel: sand, clay, and vegetable matters, constitute their principal sediments. But the torrents which

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But the most stormy stream has intervals of comparative repose, and even the Arve and Rhone deposit most of their spoils within a few leagues of the mountains from which they were torn. Frequently lakes interpose their tranquillizing waters, and receive and distribute the sediment of the river. These lacustrine sediments differ from the ordinary valley deposits of a river in their lamination, which radiates round the point where the river entered, and in deep lakes assumes a conical character. (Yates, *Ed. Phil. Journal*.) The dried beds of such lakes have a level surface, but not all plane surfaces in a valley have had this origin; on the contrary both the gentle rivers of England, and the rapid streams of more alpine countries, ever tend, by the shifting of their channels, and the equalizing effect of inundations, to distribute their sediments in planes, which fill the whole valley, and decline toward the sea with a slope corresponding to that of the river. Arrived near the sea, short torrents from alpine regions may throw rocks, pebbles, gravel, sand, and clay, in one confused mass, into the sea. But almost all the rivers whose path is long have left their coarser materials far behind; they have generally dropped much of their sandy admixture, and bring to the shore only fine earthy particles which could remain suspended in their less rapid waters. This is the contribution (principally) which the Po delivers to the Adriatic, the Ganges to the Bay of Bengal, the Mississippi to the Gulf of Mexico, the Nile and the Rhone to the Mediterranean; the Rhine, the Elbe, the Thames, and the Humber, to the German Ocean.

The mass of sediment thus brought to the sea is great; if delivered to the wide ocean and general currents (as in the case of the river Amazons, noticed by Captain Sabine) it may be carried hundreds of miles; but in still, land-locked seas, like the Baltic, Adriatic, and Bay of Bengal, the greater part is quietly dropped along the bottom and shores of the sea. Thus the extent of such gulfs and basins is gradually and rapidly contracted, their depth reduced, and preparation made for a new series of stratified rocks, perhaps hereafter, in the manifold changes of the globe, to be raised for the contemplation of future geologists.

Thus we have the whole history of river formations; gravelly deposits near the mountains; sandy and argillaceous beds toward the sea; fine silt lands where the tides and freshes meet, in the estuary, and along the coast line. Thus the river mouths are incessantly advanced into the sea, the whole coast moves forward, and a large breadth of continually enlarging flat lands borders the tidal part of the river, and constitutes those rich and noble deltas, through which the changeful stream takes its winding way, and which require, in many instances, all the care and vigilance of man to preserve from the river and the sea, which made and may again easily overwhelm them.

The extent of some of these deltas is enormous. That of the Nile is small compared to some others; but, in fact, the gift of this river to the grateful Egyptians is much more than the delta; all the valley is full of its rich and far descended sediments.

The Delta of the Ganges commences 220 miles from the sea, and its base is 200 miles (Rennell.) This would be thought a considerable deposit, even among the old sedimentary rocks. The delta of the Niger is 25,000 square miles, (Dr Fitton, *Geology of Hastings*); an accumulation of timber and transported sediments (called a raft), on the Mississippi was estimated by Darby at 286, 784,000 cubic feet, being ten miles long, and eight feet deep, and this was the produce of fifty-two years mere decay of the timber on the banks of the Mississippi.

These, like the caves, may be of almost any geological date; and it is, in fact, very difficult to decide on the claims of the different examples. It is probable that future geologists will choose to class together all the supracretaceous lacustrine deposits, and, by a general contemplation of them, arrive at valuable generalizations, which can now only dimly be foreseen. We shall offer four cases of lacustrine deposits in England and Scotland: the two oldest, of the elephantoidal era in England, and the mastodontic era in America; the next indicative of some different local condition of drainage, coeval with the existence of the Irish elk; the last descriptive of a deposit still in progress.

A remarkable occurrence of bones, in lacustrine marl, interstratified with the ossiferous diluvium of the vale of York, was fully explored by Mr Harcourt, and other members of the Yorkshire Philosophical Society. Resting upon gravel, and covered by gravel, near Market Weighton, was found a mass of fresh-water marls, to the depth of twenty-two feet, and in these lay bones of elephant, rhinoceros, horse, bison, deer, felis, wolf, birds, all, or nearly all, of extinct species. But with them lay thirteen species of land and fresh-water shells, exactly identical with types now living in the vicinity. No wearing, no unusual fractures, the teeth still in the jaws of the lion and the wolf, the bones of the leg of the horse nearly in their right situation, the horns on the skull of the ox, all the circumstances, in short, indicated a quiet deposition of the remains near the spot where the animals died. The north of England was then inhabited by elephants and lions. This part of Yorkshire was dry land in that era; and, as far as can be known, no change of level has since occurred.

The largest collections of bones of the mastodon, and other mammalia of the United States, occur in boggy grounds, called Licks, affording salt, in quest of which the herbivorous animals, wild and domestic, enter the marshy spots, and are sometimes mired. The most noted of these deposits is Big-Bone Lick, in Kentucky, occupying the bottom of a boggy valley, kept wet by a number of salt springs, which rise over a surface of several acres. The spot is thus described by Mr Cooper. "The substratum of the country is a fossiliferous limestone. At the Lick the valley is filled up to the depth of not less than thirty feet with unconsolidated beds of earth of various kinds. The uppermost of these is a light yellow clay, which, apparently, is no more than the soil brought down from the high ground by rains and land-floods. In this yellow earth are found, along the water courses, at various depths, the bones of buffaloes (bison), and other modern animals, many broken, but others quite entire. Beneath this is another thinner layer of a different soil, bearing the appearance of having been formerly the bottom of a marsh. It is more gravelly, darker coloured, softer, and contains remains of reedy plants, smaller than the cane so abundant in some parts of Kentucky, with shells of fresh-water mollusca. In this layer, and sometimes partially imbedded in a stratum of blue clay, very compact and tenacious, are deposited the bones of extinct species."—(*Reports of Brit. Assoc.*)

Mr Cooper has been at the pains to compute, from the teeth and other parts known to have been removed from Big-Bone Lick, the number of individuals requisite to furnish the specimens already carried off.

Mastodon maximus, . . .	100 individuals.
Elephas primigenius, . . .	20
Megalonyx Jeffersonii, . . .	1
Bos bombifrons,	2
Bos Pallasii,	1
Cervus Americanus,	2

Subterranean Forests, as they are termed, abound on many parts of the English and French coast. (See De la Beche's *Manual*.) The phenomena are not precisely alike, but yet generally similar in all of them. Some of them shew signs of having been prostrated in particular directions, and covered by river sediment (Tees Mouth, Lancashire, near the Humber); others are composed of drifted hazels, yews, oaks, pines, alder, &c., and covered by pine-stumps in attitude of growth (Waghen near Hull); many are extensive accumulations below the level of the sea (Frith of Tay, Swansea, Humber Banks); some are slight aggregations in old lakes (Holderness). Very often layers of blue clay, with shells of existing fresh-water mollusca, lie with peat and timber in old lakes (Holderness). Sand underlies the woody deposits of Mount's Bay; clay, of unknown depth, is the base of that on the Frith of Tay; river sediments support that of the Cambridgeshire fens; and "diluvial" clay that of Holderness. Bones of the Irish elk lie in old lakes, partly full of peat and shelly clay, in Ireland, the Isle of Man, Lancashire, and Holderness; but the more common characteristic osseous reliquiae are those of the *stag or red deer*, fallow deer, beaver, and other existing quadrupeds, birds, insects, &c. Movements of the land are commonly thought necessary to explain the position, and particularly the *level*, of these "forests."

Shell-Marl.—The best example was furnished by Mr Lyell's description of Bakie Loch, Forfarshire, which agrees remarkably with some marl deposits in Tweeddale. Here, under peat with trees, shell-marl of variable thickness and consistence occurs, resting on a loose or partially cemented sand. Under this is another bed of shell-marl, of an earthy consistence; then fine sand and detritus. Near the springs which enter the loch, and supply the calcareous matter, the marl assumes greater consistence, and, from its compact or crystalline substance, deserves the name of "Rock-marl."¹

Table of the Distribution of certain Extinct Quadrupeds.

Names of Species.	Some Localities in Caverns, Fissures, &c.	Some Localities in Alluvial and Diluvial Accumulations.	Locality in or amongst Marine Strata.
<i>Felis spelæa</i> , {	Kirkdale, Gailenreuth, Luel Vieil, Sundwich, &c.	Weighton, Val d'Arno.	
<i>Hyæna spelæa</i> , {	Kirkdale, Kent's Hole, Fouvent, Sundwich, &c.	Lawford, Val d'Arno, Kostriz.	
<i>Canis spelæus</i> , {	Kirkdale, Franconia, . . .	Weighton.	
<i>Castor</i> , . . .	Luel Vieil, . . .	Val d'Arno, . . .	Near Zurich
<i>Megatherium Cuvierii</i> , {		Buenos Ayres.	
<i>Elephas primigenius</i> , {	Kirkdale, . . .	Val d'Arno, Weighton, Essex, Norfolk, &c. &c. and throughout Europe, North of Asia, and America, . . .	Volhynia, Warsaw, Wielicka Estavayer.
<i>Mastodon maximus</i> , {		South America.	Italy, Touraine.
<i>Mastodon angustidens</i> , {		Val d'Arno, Austria, Peru, . . .	Touraine.
<i>Hippopotamus major</i> , {	Kirkdale, . . .	Val d'Arno, Essex.	
<i>Rhinoceros leptorhinus</i> , {	Franconia, Kirkdale, Nice, . . .	Siberia, England, Germany, Val d'Arno.	
<i>Cervus megaceros</i> , {	Kent's Hole, . . .	Ireland, Rheinthal.	
<i>Bos primigenius</i> , {	General, . . .	Frequent.	

¹ See Lyell in *Geol. Trans.* vol. ii. 2d Series, *Principles of Geology*, and De la Beche's *Manual*.

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Remains of the human race have often occurred in the same repositories as the animals noticed above, but almost never without sufficient proof of their later existence. In some cases distinct proof of inhumation at subsequent periods, in other cases different state of conservation, or different situation in the ossiferous deposit, have removed all doubt of this important fact. The only cases which can be considered at all doubtful, are those mentioned by MM. Tournal, Teissier, &c. in caves of Bize, &c. in the vicinity of Narbonne. In these instances, the *proof* of the posterior date of *all* the human reliquiae seems incomplete; but the balance of *opinion* appears to be decidedly in favour of the view which has so long been adopted by geologists, viz. that these northern regions were not inhabited by men during the period when elephants and hippopotami roamed in the damp forests of Germany, France, England, and Siberia.

What is the exact *geological date* of the existence of man, in other words, what is the exact point of union of historical and geological time—a most important problem—is therefore as yet wholly undetermined. Its solution must, probably, be looked for in countries nearer to the tropical regions of the Old World, where many concurring circumstances unite with the authority of Scripture in fixing the local origin of our species.

IGNEOUS ROCKS AND DISTURBANCES OF THE MODERN PERIOD.

The effects of subterranean heat have been exhibited at intervals in all the periods of geological time, measured by the deposition of stratified rocks; the resulting phenomena have been noticed at so many points on the earth's surface, as to leave no doubt that the action of heat, below the surface of the solid crust of the globe, has been, either contemporaneously or successively, as extensive as that of water above it. Certain phenomena, such as the general character of composition and the absence of organic remains, in the lowest primary strata, lead to the impression, that in the most ancient known geological period the effects of heat were at one and the same time coextensive with these strata, which is nearly the same thing as saying they were contemporaneously universal. But as we ascend in the order of strata, and come nearer, though by an unknown progression, to the modern era, the evidence of this contemporaneous great extent of the subterranean caloric influence diminishes; the effects are still striking and of the same general description and equal in violence, but more local and limited. In the older period, we found occasional interstratification of igneous rocks and marine sedimentary rocks, and other proofs of the submarine situation of the igneous agency; but in the tertiary periods new phenomena were observed, which proved the igneous agency to have burst forth on the dry land, or amidst fresh-water lakes, and to have assumed in consequence much of that peculiar character which belongs to actual volcanoes.

It is very evident that the study of volcanic action affords the only clew to a correct appreciation of the circumstances under which igneous agency exerted itself in ancient times. The exhibition of modern volcanic action takes place under a sufficient variety of circumstances to furnish an adequate basis of reasoning upon the conditions which influenced the different effects of similar agencies in earlier periods.

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The antiquity of volcanic phenomena is very great. Most of the districts in which volcanic phenomena take place, or have left evidence of their former activity, appear to have been vents for subterranean fires from the era when the district first rose above the sea. This appears certainly to be the case with Sicily, Auvergne, Naples, the

Rhenish volcanoes, and many others, though perhaps the present volcanic cones of Etna and Vesuvius may not be of such high antiquity. Many truly volcanic regions no longer contain burning mountains, and never yield streams of lava; yet by the nature of the rocks, by the phenomena of mineral springs, by the mere form of the surface, they yield evidence that volcanic forces once were active there, though now extinct, dormant, or called off to some other focus of energy. From what we learn by comparison of volcanic regions in different conditions, it appears that each volcanic vent has a definite date of origin, lives through a period of activity, and decays by gradual or intermitting stages, till nothing is left but the marks of what has been.

Continuity of Volcanic Action. This decay and extinction of volcanic vents is a phenomenon of the highest importance in reasoning on the condition and causes of the subterranean temperature. If volcanoes die away for lack of their chemical fuel, a presumption arises that the conditions of their excitement are local, limited, and exhaustible; but if this be not the case, if volcanic action only sleeps below a certain point, because it is awakened to greater and more easy manifestations elsewhere, there is no reason *a priori* to prevent our admitting for all volcanoes one general physical condition or cause.

Extent and Connection of Volcanic Action. Now it is certain, that in several instances volcanic phenomena have happened simultaneously, or rather after a short interval, at very distant points or foci of volcanic energy. Dr Daubeny observes (*Treatise on Volcanoes*), "The connexion of the volcano near the town of Pasto with those of the province of Quito, was shewn in a striking manner in 1797. A thick volume of smoke had proceeded, ever since the month of November 1796, from the volcano of Pasto, but, to the great surprise of the inhabitants of the city of that name, the smoke suddenly disappeared on the 4th February 1797. This was precisely the moment at which, 65 leagues further south, the city of Riobamba, near Tunguragua, was destroyed by a tremendous earthquake."

Humboldt (*Personal Narrative*) appears to view the higher part of the kingdom of Quito and the neighbouring Cordilleras, not as a group of distinct volcanoes, but as an immense volcanic mass, stretching from north to south, and occupying a surface of more than 600 square leagues; the lofty mountains of Cotopaxi, Tunguragua, Antisana, and Pichincha, affording so many apertures from which the fire finds vent, sometimes in one and sometimes in another.

No doubt exists of the connection of earthquakes and volcanoes. Mr Lyell observes, that from the commencement of the thirteenth to the latter half of the seventeenth century, no earthquakes are recorded in Syria and Judea; and during this interval of quiescence, the Grecian Archipelago and the coasts of Lesser Asia, Southern Italy, and Sicily, were shaken by earthquakes and alarmed by eruptions.

Geographical Distribution of Volcanoes. But much stronger proof of the great extent and connexion of the conditions of volcanic excitement, is to be found in the view of their positions on the globe. Von Buch was the first to propose a classification of volcanoes in two groups, viz. *central volcanoes* and *volcanoes in line*. Those of the Italian shores and islands, Iceland, the Azores, Canary Isles, Cape de Verd Islands, Gallapagos, Sandwich Islands, Marquesas, Society Islands, Island of Bourbon, as well as the mountains of Demavend, Ararat, &c. belong to the former class. The Greek Archipelago, the west of Australia, the Isles of Sunda, the Moluccas and Philippines, Japan, the Kurilian and Kamschatkan chains, the Aleutian Isles, the Marian Isles, the Antilles, as well as the Cordilleras of Chili, Quito, Guatemala, and Mexico, are ranked with the latter.

The extinct volcanoes of the old world, Auvergne, the

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Geology. Eifel, Northern Germany, Hungary, north of Italy, &c. belong to the class of central volcanoes.

The most remarkable line of volcanic vents on the globe, is that long chain of islands which, from Alaska, on the coasts of Russian America, passes by the Aleutian Isles, Kamschatka, the Kurilian, Japanese, Philippine, and Moluccan Islands, and then turns in a long course through Sumbawa, Java, and Sumatra, to Barren Island in the Bay of Bengal.

Active and Extinct Volcanoes. The most common division adopted in works on volcanoes separates the known volcanic districts into extinct and active volcanoes,—a distinction which seems clearer than it is; for between the burning mountain with its formidable realities, and the long silent volcanic mound, surrounded by mineral springs, and other residuary phenomena, almost every gradation can be traced. Viewing the subject generally, it is difficult to resist the idea that the exhibition of volcanic excitement is in proportion to the proximity of the sea, or other repository of water; for almost every one of the active volcanoes of the globe is situated in an island, or near the sea-coast of a continent, and many of the extinct volcanoes are on the site or in the neighbourhood of ancient lakes now dried up. The following short synopsis of the situation of active volcanoes, will shew their general proximity to the sea.

In the islands and sea-coasts of Europe.—Etna, Vesuvius, Stromboli, Volcano; several in Iceland, Jan Mayen, Santorino.

In islands of Africa.—Teneriffe, Lanzerote, Cape Verd Isles, Azores, Isle of Bourbon, Madagascar.

In islands of Asia.—Zibbel Teir in the Red Sea; an island in the Sea of Azoph; Aleutian Islands; Kurile Islands, Loo Choo, Formosa, Lucon, Fugo, Mindanao, Celebes, Ternate, Fidore, Sumbawa, Java, Sumatra, Barren Island, Banda, New Guinea, New Britain, New Ireland, Friendly Islands, Society Islands, Ladrone Islands.

On the continent of Asia, near the coasts or inland seas.—Demavend, Kamschatka.

America, in the islands.—West Indian Islands, Gallapagos.

America, near the coast.—California, Nicaragua, Guatemala, Columbia, Peru, Chili.

America, more inland.—Mexico.

The principal volcanic tracts of Europe, which all belong apparently to the tertiary and modern periods of geology, are those of the Puy de Dôme, Cantal, and Velai in France; of the Eifel; the Rhine below Andernach, near Heidelberg, and near Freyburg; the Vogelgebirge; Rhongebirge; Ebnach; north of the Lake of Constance; Hungary; Transylvania; the Grecian Archipelago. (See Daubeny on Volcanoes.)

Origin of Volcanic Vents. The origin or production of a new volcano has seldom been witnessed by competent observers. The phenomenon is, in fact, extremely rare; for though we read of new cones and craters being formed on Etna, and new islands occasionally raised from the sea, the fact in general is, that these are merely new vents to an old volcano, whose former and accustomed channels to the surface have by some circumstances been rendered incapable of giving passage to the vapours and lava of the teeming mountain. It is probable, from considering the lines of craters which belong to one of Von Buch's classes, that some great fissure or line of subterranean movement has determined the local situation of volcanic vents. Even the central volcanoes of Von Buch appear to be often related to particular centres and axes of subterranean movement; as Auvergne, the Eifel, Sicily, and others.

Origin of Volcanic Cones and Craters. Von Buch supposes in addition, that many volcanic mountains have been formed by uplifting of stratified and igneous masses into a conical or elliptical mass depressed in the centre, and to such he gives the name of Erhebungs Cratère (craters of elevation).

Mr Lyell controverts this view, and attempts to prove that, like many of the new cones of Etna, Monte Nuovo, &c., near Naples, volcanic mountains generally are craters of eruption, that is, nothing but heaps of scoriæ and ashes, and streams of lava, collected into a conical mass in consequence of issuing from a central orifice. Many volcanic mountains, probably all of a very decidedly conical shape, are formed in this manner; but certain dome-shaped hills in Auvergne are held by Dr Daubeny to be strictly referrible to elevation in mass. It is supposed that the formation of the Mexican volcano of Jorullo (1759), when, according to Humboldt, the ground rose up like a bladder for a surface of three or four square miles, to a central elevation of 324 feet, is a modern example of the truth of the hypothesis of Von Buch; and at all events, the possibility of such an origin cannot consistently be denied, if we pay attention to the many instances of elliptical elevation of stratified rocks of different ages, as at Woolhope in Herefordshire, Greenhow Hill in Yorkshire, &c. which have been brought forward of late years.

Volcanic Phases. By whatever means a volcanic vent, whether it be a cone with a crater-shaped top or any other aperture, has been formed, its augmentation can only take place by the process of eruption. Scoriæ, ashes, &c. blown from the mouth fall round and augment the cone; streams of liquid rock flowing over the edge of the crater, may, by many successive currents in different directions, produce an equal conical mouth of concrete lava, or, rushing out from the side of the cone, spread or accumulate according to the shape of the surface. These effects must differ according as the phenomenon happens in the sea or on the land. Hence Mr Scrope's distinction of subaqueous and subaërial volcanoes. Subaqueous ejections of scoriæ, &c. are subject, in the first place, to partial suspension in water, and in the next, to agitations of the liquid produced by the eruption and other causes. These act in the same direction, and tend to diffuse the disintegrated accumulations far and wide from the volcanic vent. Hence strata of very small inclination are produced round the crater, or, if any thing comparable to a volcanic cone is occasioned, the heap of large scoriæ must yield to the lateral influence of the waves, and be at length dispersed over the bed of the sea. Of the truth of this view, the modern island of Sciaccia, its rapid growth, and rapid degradation, offered good illustration.

Subaqueous eruptions of lava must also for the most part flow under the pressure of the liquid columns to various breadths on the bed of the sea, so as to form irregular stratiform masses, embossed here and there by mounds of lava, too quickly congealed to spread into the tabular form.

Thus it appears a necessary consequence of the conditions of a subaqueous volcano, that its accumulations, whether liquid or disintegrated, should be formed into broad expanded masses, having a stratiform arrangement; and this is what is always observed among the igneous rocks of ancient geological periods, unless where fissures in the rocks are filled by the irruptive lava. Thus the basalt of Teesdale and of Antrim, the porphyritic masses of Snowdonia, Cumbria, &c. have been formed.

Subaërial ejections of loose materials must of necessity be collected round the point of exit into conical layers, determined in their angle of inclination by the angle of rest of the particles, under the influence of the forces of projection and gravitation. The lavas poured out from the crater, or bursting from the flanks of the cone, must accommodate

Geology. themselves to the form of the surface, so as to mantle round the original mountain, swell into knolls at its foot, or flow away into valleys and hollows of the land, or enter the sea. All these variations are visible at Etna and Vesuvius.

Subaërial volcanic ejections may alternate with fresh-water productions (Cantal), with detritus holding bones of mammalia (Auvergne), or cover cities, as Pompeii and Herculaneum; and submarine volcanic accumulations may alternate with shelly sediments and limestones.

But there is yet another form of modern volcanic aggregates which it is of great importance to distinguish from the preceding, because of its bearing upon points of great importance in old geology. There are *subterranean volcanic products* which neither are poured into the sea nor thrown into the air, but secretly elaborated under the pressure of a solid covering, and effused into the fissures of the rocks.

Although it may reasonably be allowed that the great variety of productions ejected by subaërial volcanoes affords a good indication of the principal mineral substances generated by volcanic action, we must be cautious not to limit our notions of their combinations in the deep parts of the earth to those which are suggested by the compounds which are determined at the surface.

The degree of pressure, rate of cooling, and mass of ingredients, which are known to be important modifying conditions of molecular aggregation, are wholly different at the roots and about the surface of the immense volcanic chimneys which, like Etna and the Peak of Teneriffe, become filled with the liquid rocks whenever the subterranean pressure amounts to a particular degree.

At the base of a volcanic vent, deep in the earth or under the sea, particular mineral aggregates, slowly cooled, under great pressure, and in great masses, may, and probably do, at this day assume the largely crystalline texture and distinctness of ingredients of granite; on the bed of the sea they may flow in the state of porphyry or basalt; on the surface of the land appear as porous lava, and be blown into the air in disintegrated scoriæ, ashes, and dust.

VOLCANIC PRODUCTS.

The number of mineral substances found in volcanic ejections is very great. Nearly 100 distinct minerals have been recognised among the products of Vesuvius. But of these only very few occur in such abundance as to constitute any great portion of the lava or scoriæ.

It is almost correct to say that the principal portion of the masses of all the known volcanoes is constituted of two minerals,—felspar and augite.

According to the predominance of one or other of these ingredients, the lava currents may generally be classed as feldspathic lava, or augitic lava, but the permutations of ingredients is so frequent, that no definite mode of specific nomenclature has more than a local value. Mr Scrope forms the groups Trachyte, Graystone, Basalt, and in each proposes many subdivisions. Trachyte is divided by Beudant upon different principles. Perhaps it is useless to attempt the drawing of lines where nature has permitted none to appear. Trachytic rocks, as in the Siebengebirge, Hungary, Auvergne, are composed of crystals of glassy felspar alone, or mixed with mica, hornblende, titaniferous iron, &c. and confusedly aggregated or cemented by compact felspar. Porphyritic trachyte, like porphyritic granite, holds large crystals of felspar (Siebengebirge.) On the other hand, in the graystone of Mr Scrope augite or hornblende, or both, predominate over the felspar. In many cases the felspar is partially or entirely replaced by other minerals, as leucite, melilite, hauyne, olivine, &c.

Geology. According to the rate of cooling and other circumstances, the aggregation of these ingredients varies much. Lava which has flowed down into water, and been consolidated under even slight pressure, is found more condensed than that which has hardened in air, and become cellular by the free extrication of gaseous bubbles in the hot mass. Sudden cooling of lava gives it a glassy character, as obsidian, pearlstone, &c.; slow cooling develops its crystalline, granular, and earthy texture. Gaseous expansion in a fluid mass of lava may convert it to cellular pumice, or scatter it into dust or scoriæ, which are thrown out of the crater.

Again, the scoriæ and dust are often collected by water into sedimentary deposits, called volcanic tuff, conglomerate, puzzolana, and trap. It is this kind of accumulation which covers Herculaneum, while Pompeii seems to have been buried in dry ashes.

Besides the solidifying mineral aggregates which flow over their summits or burst out from their flanks, and the disintegrated showers of scoriæ and ashes which fall round them, many volcanoes pour out floods of water, variously impregnated with salts, and mixed with earthy sediments; and all discharge volumes of gaseous matter and steam, and sublimed mineral substances.

The gases are chlorine, sulphuretted hydrogen, sulphuric acid, carbonic acid, nitrogen, (Daubeny). Sir H. Davy found the sublimations of Vesuvius to be chloride of sodium, chloride of iron, sulphate of soda, chloride of potassium, sulphate of potash, oxide of copper, chloride of cobalt.

PHENOMENA OF EXTINCT VOLCANOES.

Long after volcanic fires have ceased to be visible externally, the regions which they once desolated are the theatre of residuary phenomena of considerable importance. In the neighbourhood of Vesuvius the ancient trachytic crater called the Solfatara, is still the channel through which come to the surface abundant vapours of sulphuretted hydrogen. Hot waters still gush out from the Monte Nuovo and the Lago Agnano. Carbonic acid gas still fills the Grotto del Cane, and rises with the springs of water in Auvergne and the Eifel. Earthquakes have often ravaged the districts of Asia Minor, where, in very ancient times, volcanic fires were lighted: and, by combining these and other indications, we find that it is rather from want of communication to the surface than from any real stifling of their energies, that volcanoes appear to become extinct.

If we were to admit, with Dr Daubeny, that the phenomena of hot-springs indicated a slow volcanic action still going on below the point of efflux, (and the arguments he has brought from the gases which they evolve¹ appear important), it would follow that few districts of the globe are exempt from such slow action of volcanic forces below them. But, on considering the cases where the same gases are evolved from cold springs, Harrowgate, Tunbridge, &c. we find ourselves conducted to a more general result, viz. that in places where *disturbed stratification* occurs, or vertical movements have happened, such as to render it certain, or very probable, that a communication, arising from solution of continuity of the strata, exists from the surface to great depths, the springs which issue have generally a saline muriatiferous or mineral impregnation, and evolve gases, (sulphuretted hydrogen, azote, carbonic acid,) which correspond to those of volcanic regions, and indicate that, at the present day, at some depths from the surface, the chemical agencies consequent on volcanic action or high temperature are continually going on, or momentarily excitable. The temperature of such springs may perhaps be a good indication of the nearness of the source of heat, provided allowance be made for the quantity of water issuing.

¹ Report to the British Association.

That such a connexion exists is perhaps universally allowed; but it is also capable of sufficient proof that earthquakes generally precede volcanic eruptions, and this sometimes for a considerable period, increasing in violence until the eruption happens and relieves the subterranean pressure.

On the 26th of March 1812 Caraccas was utterly destroyed by an earthquake, and a mountain near it subsided. On the 27th April the eruptions of the Souffrier, in St Vincent's, began.

In the year 63 of our era earthquakes began to disturb the vicinity of Pompeii, and in 79, after a succession of these phenomena, the fires of Vesuvius were rekindled.

The extraordinary eruption of Jorullo in 1759, followed upon extraordinary earthquakes; and the unparalleled excitements of Skaptar Jokul in 1783, were heralded by similar precursors.

The elevation of Monte Nuovo in 1538 was, in like manner, indicated by previous violent subterranean disturbances.¹ The connexion of earthquakes and volcanic eruptions is that of two effects of one cause. In the Canary Isles, the Peak of Teneriffe is almost a continual safety valve, which drains off the gases, &c. and so frees the surrounding islands from earthquakes.

Earthquakes.—These alarming indications of subterranean disturbances are far more extensively felt than in the mere vicinity of the volcanic cones, whose renewed activity they often betoken. The numerous concussions which were experienced in England in the 11th, 12th, 13th, 17th, and 18th centuries, seem as much dependent on the Icelandic as on the Italian volcanoes. Those which have affected all the countries north of the Mediterranean; the convulsive movements of Asia Minor in the early Christian eras; those of India, are far removed from any centres of volcanic excitement. We also find that, in some instances, earthquakes have prevailed for years, and done great mischief, (as before the earliest recorded eruptions of Vesuvius) before the throes of nature have been relieved by the birth of volcanic fires. Hence, it appears that the earthquake is really the greater and more general, and the volcano the lesser and more limited, effect of a cause more general than either.

The characteristic effect of earthquakes is the displacement of the solid mass of the ground, and the violent agitation of the liquid parts. A passing earthquake is known by a peculiar vibration, or rather undulation of the solid ground, which tends to throw down unstable bodies, and to communicate vertical or oblique impulses to all. It is not properly a vibration, but a forcible *rolling* of the solid crust of the globe once, twice, or several times. In some instances the effects are permanently indicated by opened fissures, subsided grounds, drained wells, elevated lines of country; but more frequently the yawning ground closes again, and the convulsion passes on. It has been observed that the apparent direction of the disturbance is the same in the same earthquake; that the celerity of the movement is very great, but not instantaneous, and, in some instances, particular lines of country are found to be more commonly affected than others.

It has been found that perhaps the greatest effects of earthquakes happen on the sea-coast (Lisbon, 1755; Port-Royal, 1692; Catania, 1693); that the shock is felt in the sea as well as upon the land, vessels being struck upward by a heavy blow, which could not be by *vibration*, and

waves retiring and reflowing at immense distances of coast from the places of principal disturbance.

From all the circumstances, it is apparent that earthquakes are the effect of a powerful mechanical force, accumulated to a maximum at particular points, and along certain lines, at a considerable depth below the surface. The rolling motion of the ground is a real undulation of the flexible crust of the globe, consequent upon fluctuations of an interior fluid, liquid or gaseous, which is very extensively spread below the solid rocks, and liable to irregular disturbances, which are, at least partially, relieved by volcanic eruptions.

On looking carefully at the recorded permanent effects of earthquakes, we find reason to believe that the most considerable displacements of parts of the land have been productive of local depression,—that, as the most frequent result, the land has sunk. It was so at Port-Royal in 1692; at Lisbon in 1755; at Caraccas in 1812. We read of Mount Acraus falling into the sea in 876; of Pompeiopolis being half swallowed up in 541; of Grecian cities overwhelmed in the deep; at Darlington ground fell in 1179; at West Ham in Kent in 1596; near Bordeaux in 1660.

But cases of at least temporary rise of the land also occur. In 1556, on the west coast of South America vessels were left dry far from their ancient place of mooring. In 1110, the Trent was dry at Nottingham for a whole day; in 1158, the Thames was dry at London. According to Mrs Graham, the coast of Chili, for the distance of 100 miles, rose to a height of three or four feet above its ordinary level, indications appearing that many such accidents had happened before: this case has been the subject of much discussion. Permanent subsidences and elevations happened in the valley of the Indus in 1809.

Upon the whole, the frightful devastations ascribed to earthquakes are confined to particular regions of the globe, not far removed from the sites where volcanoes now are, or formerly were, in extreme activity. The permanent changes of level which they have produced in the last 1800 years, are very slight and difficult to substantiate. From 1048 to 1800 (752 years), no less than forty-five earthquakes were recorded in England alone; and no doubt many were unobserved; yet what remarkable permanent effects were ascribed to them even by the credulous chroniclers of the middle ages? After exploring all the exaggerated descriptions of the phenomena, written in the midst of fear and alarm, we rise from the perusal, satisfied that the effects of earthquakes are of the same kind as those performed by ancient convulsive movements of the globe, and similarly connected with variations of interior heat, but immeasurably inferior in amount. If modern earthquakes and volcanic fires be proportioned to the modern rate of variation of interior temperature, how much greater must have been the variations of heat corresponding to the incomparably greater convulsions of ancient date? It may be said, perhaps, that our period of 2000 years' experience is nothing to the long series of geological ages consumed in the production of these greater effects; it may be said, that such extensive displacements, whether effected by few convulsive movements, or many smaller disturbances, are equally a function of the time elapsed; but, surely, if we find the modern feeble earthquake and volcanic fire adequate to restore momentarily the equilibrium of the disturbed interior forces, they are the measure of such disturbances.

There may indeed be a residual phenomenon; the equilibrium may be only partially restored, and the uncompen-

¹ See Lyell's *Principles of Geology*.

Geology. sated portions may be terms of a series continually augmenting, till it be satisfied by a great convulsion; this may be: but if so, the point is at once conceded; the inefficacy of earthquakes in producing such effects as the permanent uplifting of a mountain chain is granted, and for such an effect we must look to some other and more adequate cause than mere volcanic excitement. What, then, is volcanic excitement?

HYPOTHESES OF VOLCANIC ACTION.

Discarding the antiquated notion of volcanic phenomena depending on the combustion of coal-beds, the decomposition of sulphuretted metals, &c., we have only two hypotheses of volcanic action to consider. The authors of these speculations call them *theories*; but if we recollect how very insufficiently the laws of volcanic action have been developed, we shall not readily grant that any great progress has been made in developing the laws of causation; till this is done there is no true theory.

The hypothesis proposed by Cordier, of a heated interior mass mechanically disturbed, has been improved by the additional postulate, that the heated interior of the globe is chemically disturbed by access of water and other causes, and in this state is in harmony with the general view of Leibnitz concerning the changing conditions of the globe, and with the course of partial inferences contained in the preceding pages. But these views and inferences must be further examined and more fully admitted before any hypothesis grounded on them can be adopted by more than a party in geology. This examination we shall briefly attempt hereafter, but, at present, the truth of the doctrine of volcanic action being dependent on local thermal disturbances, must rest upon its power of explaining phenomena under the disadvantages of the want of knowing the laws of these phenomena.

Another hypothesis was proposed by Davy, and, for a time, partially adopted by several chemists. Seeing the remarkable ignition and other effects of strong chemical action consequent on the excessive attraction of the metallic bases of the alkalis for oxygen, it was easy to suppose these substances existing uncombined in the interior of the globe, to imagine the local addition of water, or other substances containing oxygen, and thus to account for the violent ignition, alkaline products, steam, convulsive movements, and other phenomena of volcanoes. Dr Daubeny, the most strenuous supporter of this view in our days, places it on its true basis, viz. the power which it possesses of explaining phenomena. Thus both the hypotheses refer themselves to one and the same test.

It is, perhaps, commonly imagined that these hypotheses exclude one another, but this is unnecessary. Though the globe be hot within, it may contain uncombined the metallic bases of the earths and alkalis. Though it be to them that volcanic phenomena are owing, their action would not be impeded by a high temperature of the subterranean region, but, on the contrary, exalted.

It is further remarkable, that the points of agreement are great. It is requisite, upon either view, that water be admitted to a hot mass, or to one capable of becoming so; that chemical processes happen, in which oxygen is absorbed, and hydrogen and other gases released. The sublimation of sulphur, salts, metals, &c. is just as intelligible one way as the other. The situation of volcanoes in islands, on sea-coasts, and generally near water, is a consequence of either hypothesis; the long duration of volcanic foci,—the intermission of their action,—the gradual extinction of some of them, are quite as easily understood the one way as the other. Wherein, then, do they really differ? Principally in the development under the bias of the respective partizans. The hypothesis of Dr Daubeny is chiefly directed to the explanation of the chemical products in the

order of their succession, and, so far as the chemical questions are concerned, it appears to answer the conditions required. The other speculation has been found more powerful in explaining the great extent of the subterranean movements to which volcanic fires are but a local appendage; it is more satisfactory, when viewed in connexion with older pyrogenous rocks and older tremors of the globe. Thus the Mechanical theory, as Cordier's hypothesis has been termed, explains better the mechanical effects; the Chemical theory, as Dr Daubeny's speculation has been named, fits better to the chemical phenomena.

But as they do not exclude one another, as both *may be true*, why are they put in such determinate opposition? What the substances are which occur at the base of volcanoes, is to be found by chemical researches; in what state they are as to temperature, fluidity, density, &c. is the province of general physics to ascertain.

We may, therefore, very consistently agree with Cordier, Von Buch, and De Beaumont, in viewing the origin of volcanic fissures as a case of violent displacement of the crust of the globe, arising from change of the thermal state of an interior fluid nucleus, and in ascribing to this mechanical condition the great extent of earthquakes from the bases of volcanic regions, and yet adopt at least the principle of Dr Daubeny's hypothesis. If we were to adopt completely the opinions of this writer, we should have the following view of the series of chemical processes.

The interior parts of the globe, whether hot or cold, fluid or concrete, consist, at least in part, of the metallic bases of the alkalis and earths, and of some metals; to this water, generally sea-water, and atmospheric air find access through irregular and variable channels in the rocks. The consequence is oxidation of the alkaline metals, potassium and sodium, the earthy metals silicium, aluminum, &c., and iron and other ordinary metals; a large volume of hydrogen will thus be liberated from its aqueous combination with oxygen; the atmospheric air will also be decomposed, and its nitrogen set free; chlorine will be liberated from its combination with sodium; sulphur will be disengaged from various mineral combinations in the superior rocks. Then the oxygen will combine with sulphur to constitute sulphureous acid gas, and with hydrogen to form steam; the oxygen being consumed, hydrogen will unite with sulphur, and form sulphuretted hydrogen, and with nitrogen to form ammonia, which, neutralized by chlorine, becomes sal ammoniac.

Besides these, which may be called the primary chemical phenomena, there may be noticed secondary phenomena depending on the mere communication of heat to the rocks above. Such are the extrication of carbonic acid gas from calcareous rocks, the sublimation of sulphur so as to permit its combination with oxygen, to form sulphurous acid gas, and with hydrogen to constitute sulphuretted hydrogen. These and other effects are equally necessary on either hypothesis, and must be supposed to continue long after the primary chemical phenomena have ceased; as indeed, in old volcanic tracts, we know to be the case. In fact, along lines of dislocation of far higher antiquity than any merely volcanic mountains, we find the same phenomena of hot springs, carbonic acid, nitrogen, sulphuretted hydrogen, &c., and it thus appears almost a necessary consequence, that the heat, below a given point of the earth's surface, though no proper volcanic phenomena be there visible, is almost inexhaustible. Should not these considerations have weight in determining geologists not to refuse either the general thermal, or the local chemical hypothesis of volcanoes? Both are perhaps true, though we may not have the power of explaining by them all the yet imperfectly known phenomena, depending on the changing temperature and chemical conditions of the subterranean regions.

STATE OF GEOLOGICAL THEORY.

Geology. The caution which has been infused into every branch of natural science has been productive of excellent fruits in geology. Within a hundred years its whole aspect has been changed; from a mass of crude speculations fitted to inaccurate observations, it has gradually grown up to a system of sound, though limited, inferences, connected by some very probable generalizations, and supported by independent mathematical reasoning. The *Laws of Phenomena* are unfolded to a considerable extent, and, in the opinion of eminent men of science, the time is at hand for effectual researches into the *laws of causation*. Not that the labours of observation should, for an instant, be suspended; *they* are the most important of all the means of advancing geology: on the contrary, they ought to be continually excited by new impulses, and turned into more profitable directions by the first, however rude, indications of theory. The state of geology is so prosperous, that its numerous cultivators may well agree to divide their forces so as to accomplish combined movements; to advance on the one hand the mass of generalized phenomena, and on the other to multiply the points of contact between dynamical, chemical, and vital laws, and the results of geological inquiry.

In the exhibition of this subject, it is almost singular how useless and even trifling a thing it is to refer to the ancient opinions on the constitution and changes of the globe, which modern sceptics concerning the progress of geology seem to have ever before their eyes as spectra, warning them of the danger of listening to the reasoning of the mathematician, the astronomer, the chemist, or the zoologist, when applied to the history of the globe. Were it not for this salutary terror which they inspire even in bold minds, the reveries of Whiston, Catcott, and Whitehurst, perhaps we may add of Werner and Hutton, as to the origin and changes of the globe, would be speedily forgotten. Even the beautiful work of Playfair loses its importance when fairly poised against the growing mass of partial geological truths; and perhaps we ought to look upon the hypotheses of Von Buch, De Beaumont, and Lyell, as *over generalizations*, proper to excite and direct inquiry on particular points, and thus likely to have a temporary use rather than a permanent influence. However this may be, it is certain that the researches of the last fifty years have justified the words of Herschel: they have brought the grand problem of the history of the globe fairly within the circle of inductive science, linked it inseparably with the progress of physical science and natural history, so that its progress or retardation can only be proportioned to that of the general mass of human knowledge.

From this an important conclusion results: the close union and strict dependence of geological reasoning on the advancement of other sciences, must place a strong restraint on the presumption and confidence with which crude hypotheses have been often advanced by men of mere observation; in future it will be trusted to minds of a higher order, habitually exercised in the combination of natural laws, to propose leading views in geology. It is already known that a mathematical basis exists for geology as well as for astronomy, and the search for this cannot long be unsuccessful in the accurate hands of the analysts of France, Germany, and Cambridge.

So rapid is their progress that, even while we write, a large accession of knowledge is brought by Mr Hopkins, in a memoir on Physical Geology, presented to the Cambridge Philosophical Society, on the hitherto obscure subject of subterranean movements, and other investigations concerning the interior of the globe are opening upon us. The following view of the state of theory on several funda-

mental points cannot therefore be complete, perhaps not even free from inaccuracy.

Though inferences from geological phenomena, and deductions from assumed first principles in theory, may be almost infinitely varied, according to the extent of the data or the generality of the principles; yet, in fact, all theoretical views in geology, which can be considered general, are reduced to two types; the deductive speculations of Leibnitz, and the inductive hypotheses of Hutton. These are really and necessarily different, and whoever ventures to choose one or other of these great leaders, must in effect decide for himself the following important question:—

Are the disturbances of the statical condition of the terrestrial forces of organic and inorganic nature of a periodical character merely, so that in any sufficiently long period embracing all the cycles of their variations, the sum of their effects is equal to the sum of a corresponding earlier or later period, which is Dr Hutton's view put to extreme; or, are these disturbances of the nature of a series whose successive terms, (whether a single disturbance or cycles of periodical disturbances), differ from one another in any regular progression? (as Leibnitz supposes.)

This question cannot be answered upon analogy merely. Though the planetary system exhibits in all its perturbations a character of variation, such that the sum of the movements taken in any sufficiently long period is found to be constant, and the whole system permanent, unless the extraneous influence of the ether tend to slowly alter its condition, we cannot deduce that the parts of this system shall, *in matters of another kind*, have the like character of circular perpetuity. Nor, on the other hand, because of the many proofs of great convulsions in ancient periods, and of the rarity or even absence of such phenomena in historical times, may we conclude that such convulsions will never be repeated. There may be a periodicity of these great disturbances of the solid globe, as we know there is of the lesser irregularities of the atmosphere surrounding it.

This great question is then to be tried by the applicability of one or other of the leading principles which it involves to the explanation of the phenomena of all geological periods, and the only thing remaining to be settled is the degree of preparation in which we find ourselves for such a trial of principles.

Have we data, or laws of phenomena, sufficiently certain and known in all their relations to allow of ascending by inferences to one of the rival principles, or of testing deductions from the other?

It is probable that we have not such knowledge. For neither do we know fully the present state of operation of terrestrial forces, including, of course, their submarine effects, nor their condition at any one former period; and it is only by a rigorous and careful scrutiny, and comparison of many different periods, that any just determination can be formed as to the laws which regulate the variation of the forces. The utmost, then, which can be expected is a presumption in favour of one or the other theoretical principle, according to its observed correspondence with the succession of phenomena which are best known.

Even this task we shall not attempt. Instead of it we shall employ a particular consideration really common to both of them, though in their development under the hands of partizans, it has come to be almost exclusively associated with the Leibnitzian speculation. Either of the principles previously contrasted admits of being developed in two modes; according to both of them the changes now going on upon the globe may be part of a long series of

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similar or gradually changing phenomena, never interrupted in their operations by extraordinary exertions of the same or different forces. This is Mr Lyell's doctrine; or the present may be viewed as a period of ordinary action of terrestrial forces, similar to many which have gone before, and which have been preceded and terminated by greater and more violent effects of intermitting agencies. (This is the view of M. De Beaumont.)

It is certain that unless this limited question can be disposed of the general principles cannot be properly examined, and in the discussion of even this really practicable problem all the knowledge yet gathered in geology may perhaps be found inadequate. It will, however, be useful to make the attempt, if only for the purpose of pointing out the lines of research on which geological observation may be profitably directed.

In the system of continual compensation among the agencies of terrestrial nature, deluges and convulsions, greater than those of the modern period, have, strictly speaking, no place; or if we relax a little the rigidity of the dogma, and allow that, by a fortuitous combination of circumstances, greater movements and inundations may have happened than have been recorded in the last thousand years or so, at least these must be shewn to be perfectly consistent with the ordinary diurnal measure of the influential agencies. For example, a lake may be slowly emptied by erosion or suddenly by an earthquake; the effects are very different; but the agencies equally belong to the present system of nature. Great effects may thus be performed, in consequence of particular combinations, by very moderate measures of force; but in applying this system to older phenomena, we must examine the *direct effects*: convulsionary movements must be the measure of disturbing forces, and diluvial effects the guide to inferences concerning cataclysmal agencies.

ORIGIN OF THE MATERIALS IN THE CRUST OF THE GLOBE.

The compound nature of these materials is a subject of great interest in any theory of the changes of the globe. When we consider the various minerals included in one rock, as granite; the definite chemical formula which represents the attractive forces of each of these; the molecular and elementary constitution of the different parts of each; and recollect that any one of these molecules and elements has various physical properties, how improbable does it appear that we shall ever arrive at a knowledge of the changes of condition through which these unchanging particles have passed! Yet it is almost impossible to avoid the endeavour, useless though it be, to separate these particles in imagination, and to represent them to the mind in a state of individual, though associated existence.

This is what Laplace and Herschel have expressed when they presented, as the result of their profound reflections, the speculation of this globe originating from the condensation of a gaseous expansion in space—a notion often extended to the other planets, and supposed to be in harmony with the common direction of their motion round the sun, the nearly coincident planes of their orbits, and other less striking circumstances. That such gaseous or vaporous expansions exist in space is known both by observation of comets, and of nebulae.

Perhaps this view, as it is certainly the most elevated, is also the most correct hypothesis of the early formation of the globe; but it would be unfair to employ so speculative an argument against the doctrine of continual compensation among the agencies of Nature, because this was proposed only for the terraqueous globe. Given, then, the globe reduced from its gaseous expansion, we may proceed to inquire into the proximate origin of its ancient rocks. Here a real discordance arises between the two systems

compared. While describing the primary strata, we have shewn the grounds for believing them to be derivative aqueous from primitive igneous rocks; but Mr Lyell, in his ingenious development of the Huttonian philosophy adds to this a reverse proceeding. According to his view the sedimentary aggregates from water at the surface of the globe, are derived from other such rocks, or from pyrogenous products; but whatever was their proximate origin, they change again in the deeper parts of the earth, by gradual transformation into crystalline or igneous rocks. So that the mechanical agency of water above, and the transforming agency of heat below, are, in this hypothesis, antagonist forces, separated by a zone of rocks (the crust of the earth, as it is technically called) which above are of the aqueous, but below of the igneous kingdom.

Between these two polarities, so to speak, the particles of the exterior parts of the earth continually circulate. Fire raises matter from below: water wears away the high parts of the surface, and adds to that load of strata which in the lower part is hourly changing to granitic and other crystalline rocks, "equal quantities in equal times."

In support of this view, only local and limited facts can be adduced; but these, as far as they go, are important. It is found that earthy limestones, such as commonly occur in secondary strata, are converted, by heat and proximity to pyrogenous rocks, into crystalline marble, such as occurs in primary strata (Kaiserstuhl, Teesdale, Antrim); that lias shales assume the aspect of clay-slate (Vale of Chamouni) near the primary rocks; that common sandstone becomes quartz-rock under the influence of heat (Caer Caradoc). Hence, as a consequence, we infer the consolidation, and many other characters of primary strata, to be the effect of heat. But this falls short of the proof required, which must be to the extent of shewing, not the changes of secondary to primary strata, but the changes of these into granite, and other crystalline rocks generally. Satisfactory proof of this nature and to this extent, is, we believe, nowhere afforded.

Moreover, what has been said before of the character and origin of the primary strata, their relation to the development of organic life, and other circumstances, appears sufficient to shew that their formation is, in some important respects, of a different kind from that of secondary sedimentary rocks; that the influencing conditions as to heat and watery agency were dissimilar; that the globe was then really in a different state generally. If so, we must certainly reject the doctrine of continual uniformity of natural operations, and admit alternating periods of different modes and measures of mechanical and chemical action. It is probable, then, that the successive systems of strata which have been described, are all that have been formed above the original crystalline rocks by the operations of water.

ORIGIN OF CONVULSIVE MOVEMENTS OF THE CRUST OF THE GLOBE.

Periods of Occurrence.—The proofs of the occurrence of such have already been given. Many examples have also been presented. It remains to ascertain what progress has been made towards discovering the cause.

It is certain that convulsive movements have happened at various periods during the deposition of the strata; and, notwithstanding the difficulties noticed in an earlier part of this essay, as to the determining of their exact geological date, there is already collected a great mass of information on the subject. One of the most important results yet arrived at, is the conviction that the time occupied in these convulsions was very short, compared to that which was consumed in the deposition of the strata; short periods of convulsion alternated with long periods of ordinary action. This at once decides the question as to the uniformity of the effects of natural agencies in the negative. It is also

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Geology. found that the effects of these convulsions were very extensive. The exact contemporaneity of those which followed the Plynlymmon rocks of Cumberland, and the slaty rocks of North Wales and Cornwall, may not be proved, and is not, for this part of the subject, very important. They happened within a comparatively short period, so as to shew that the spasmodic action was extensively felt within certain limits of geological chronology; in quarters where it had not been experienced before; and the general unconformity of stratification between the primary and secondary strata, shews that an almost universal disturbance or series of disturbances happened within these limits.

Magnitude of Disturbance.—The extent of the dislocations effected by particular convulsions is really enormous, and puts to shame the utmost exertion of a succession of modern earthquakes for many thousands of years. The Penine region of the north of England, elevated posterior to the era of coal-measures, is defined on three sides by dislocations of 1000, 2000, 3000, and more feet; and there is, perhaps, as little reason to suppose that more than one effort was employed on any one of these sides, as in the case of an ordinary fault. Such faults, indeed, sometimes occasion depression of several hundred feet; but seldom for such great lengths as the Penine and Craven disturbances.

It is not easy, nor perhaps possible, to prove that single efforts have raised the Grampian or Snowdonian chains to their present elevations; yet, in many cases, it is hardly to be supposed that more than one exertion of force has been applied to straight anticlinal axes like those of the Malvern Hills, the Caradoc Hills, the Ribblesdale Ridges, and others of considerable extent.

Systems of Disturbance.—From careful inquiries it is found possible to range the disturbances into systems related to geological time, so as to present proofs of a definite number of considerable convulsions having visited a particular region. Thus, in the British Isles, the following systems of disturbance occur in the particular periods mentioned.

First Great System.—After the deposition of the Cambrian slates. The Grampians and Lammermuir; the ranges of Donegal and Cavan; the Cumbrian Mountains; Snowdonia; the Ocrynian Chain of Devon and Cornwall; are supposed to have been uplifted at this time.

Second Great System.—After the deposition of the coal-measures. The greater number of dislocations in the coal-fields of Great Britain; the great Penine Fault, Craven Fault, and Ribblesdale Anticlinal; the Derbyshire Faults; those of Mendip, South Wales, were then produced.

Third System.—After the deposition of some parts of the New Red Sandstone strata. The Tynedale Fault; Faults in the coal-fields of Shropshire and Dudley; on the northern border of Derbyshire; the ridge prolonged from the Breiddin Hills.

Fourth System.—After the Oolitic period. In Yorkshire and Dorsetshire.

Fifth System.—After the Marine Tertiaries of the South of England, Isle of Wight, &c.

On turning to the continent of Europe, we find that M. De Beaumont, besides recognising these five systems, proposes several others, amounting in all to twelve; but we shall only add the two which have affected the Alps in periods probably later than any of those of the British convulsions.

The System of the Western Alps, which appears to have followed upon the deposition of tertiary strata of the age of the Touraine beds (Meiocene, Lyell).

Geology. The System of the Eastern Alps, parallel to the vale of the Danube. Some supratertiary or diluvial beds are stated to be disturbed by this convulsion.

M. De Beaumont suggests that the elevation of the Andes may have been posterior to all these; and a curious though inexact corroboration of this opinion has been lately furnished by Mr Darwin, who finds, in the southern parts of the chain, strata of extremely modern date uplifted to the height of several thousand feet.

In North America there appears, according to Professor Rogers, reason to suppose that, since the disturbances of the primary and carboniferous strata, the whole secondary and tertiary periods of geology have left few traces of any important convulsive movements.

Direction of Convulsive Movements.—The first notions on this subject were formed by miners, who in the course of their experience observed, as a fact of great practical importance to their art, that the mineral veins which were most generally and uniformly productive ranged east and west, or nearly; and that these *right running* veins were divided by *cross-courses*, passing north and south, or nearly. Not that there are no other directions of veins and cross-courses, but, amidst many directions, these prevail. Cornwall, Wales, Cumberland, the Penine limestone region, Brittany, the Harz, the Hungarian mines, and even Mexico, appear to confirm this law suggested by practical men. It is very difficult, or rather impossible, to explain it; but we may remark, that, in many cases, the direction of mineral veins follows that of the natural joints and fissures produced by consolidation of the rocks; and that it is very conceivable that electrical currents, or other polarizing agents, might communicate to such fissures one or more definite directions. In fact, it is proved that in Yorkshire, Derbyshire, and other large tracts, these fissures have definite directions, mostly rectangular to one another.

But it is to M. De Beaumont that we owe the proposal of the direction of convulsive movements, as a new and important problem in geology. He supposes that disturbances of the same system or geological era are parallel to a certain great circle of the sphere; that those of different periods are related to different circles, the poles of these circular systems being very irregularly posited on the globe. There are facts which make for and against this hypothesis, but it is difficult, in the present state of our knowledge, to come to a right conclusion on the matter. It is very difficult to know the relative ages of *distant* convulsions, because the lines of contemporaneous stratification are often entirely unknown. Adjacent convulsions, even if parallel, cannot prove a rule which is to apply to a whole circle; moreover, local variations of a line of convulsion sometimes derange all the reasoning.

Instances in favour of the view of M. de Beaumont may be found in the British islands,—none more remarkable than the north-east and south-west axes of anticlinal elevation, which compose the first great British system of disturbed strata. Less extensive analogy obtains among the many anticlinals of Ribblesdale, which belongs to the second system; but this also ranges north-east and south-west, or east-north-east and west-south-west; while of other lines of the same date, in the same region, one, the Penine Fault, ranges north-north-east, and north-north-west; another, the Craven Fault, ranges west-north-west. If the South Wales system be contemporaneous (and it has not been proved to be otherwise), east and west directions must be added to these various lines; and what makes the whole more perplexing, is the recurrence of east and west directions in the post-tertiary, or fifth English system, between the basins of Hampshire and London.

Under these circumstances, it is clearly impossible to adopt De Beaumont's hypothesis, for want of evidence either exact or extensive enough to substantiate it. But

Geology. yet entirely to reject the principle which it involves, would be not only rash, but positively contradictory to important facts. That some symmetrical accordance does really exist, and is traceable between the dislocations of a particular age in a particular region, is certain. Some cases are known of this symmetry being more extensively recognised. We may therefore continue our inquiries, not to test the hypothesis of De Beaumont, but to find out what is the truth.

Results of Observation.—In Mr Murchison's notices of the silurian system, and the igneous rocks associated therewith, are many proofs of the local parallelism of ridges of trap, and anticlinal axes in these ancient rocks, combined with some general directions of dislocation. The prevailing strike of all these deposits is north-east and south-west, or parallel to the Snowdonian chain, from Shropshire to the mouth of the Towey, a range of 100 miles. Within this space are numerous minor axes of dislocation, short, but parallel to the same great strike of the beds; the beds dipping north-west and south-east, from ridges of trap. This general line of dislocation is broken through by transverse rents and fissures. A north-eastern strike belongs to the Ludlow rocks and the old red sandstone. On the eastern side of the red sandstone of Herefordshire, the ridges of Abberley and Malvern point north and south, but are complicated by minor ridges running in different directions. They are posterior to the coal formation.¹

In the mountain limestone tracts of Yorkshire, the dislocations present the following general characters:—The faults and mineral veins have a tendency to range at right angles to one another; the lesser faults and veins terminate in the greater to which they are rectangular. Where the great or Penine fault changes its direction, the veins also change. The intersection of the branches of the Penine fault with the main stem, though one of these branches is not of the same age, is nearly perpendicular. In the Ribblesdale system of anticlinals, many parallel ridges east-north-east and west-south-west occur, and these are subject to very frequent cross-rolls or undulations, which break them into oval quaquaversal elevations. Mineral veins tend to cross these axes (one goes along an axis.) The Ribblesdale anticlinals are directed at right angles toward the Craven fault, and near this fault some of them bend and turn to coincide in its direction. "If we conceive all the country south of that fault to have undergone a vast relative depression, and that at right angles to the line of the fault many parallel undulations sprung out, which arrived at their maximum of curvature a short distance from the fault, we shall have a right notion of the case."²

Results of Mathematical Inquiry. It is evident that the preceding results of observation, coupled with the experience of miners and many other circumstances, point to some common principle, which must recognise as one of its results, a tendency to local parallelism and rectangulation among the lines of dislocation in a given region. A valuable contribution for this object has lately been added to geology by Mr Hopkins (*Camb. Trans.*), who, from very simple and probable assumed conditions of the crust of the globe, has deduced mathematically a series of dynamical results for comparison with the observed laws of phenomena. The following extract will explain his views and methods of inquiry:—"The hypotheses from which I set out, with respect to the action of the elevatory force, are, I conceive, as simple as the nature of the subject can admit of. I assume this force to act under portions of the earth's crust of considerable extent, at any assignable depth, either with uniform intensity at every point, or in some cases with a somewhat greater intensity at particular points; as for in-

stance, at points along the line of maximum elevation of an elevated range, or at other points where the actual phenomena seem to indicate a more than ordinary energy of this subterranean action. I suppose this elevatory force, whatever may be its origin, to act upon the lower surface of the uplifted mass, through the medium of some fluid, which may be conceived to be an elastic vapour, or, in other cases, a mass of matter in a state of fusion from heat. Every geologist, I conceive, who admits the action of elevatory forces at all, will be disposed to admit the legitimacy of these assumptions.

"The first effect of an elevatory force, will of course be to raise the mass under which it acts, and to place it in a state of extension, and consequently of tension. The increase of intensity in the elevatory force, might be so rapid as to give it the character of an impulsive force, in which case it would be impossible to calculate the dislocating effects of it. This intensity and that of the consequent tension, will therefore be always assumed to increase continuously, till the tension becomes sufficient to rupture the mass, thus producing fissures and dislocations, the nature and position of which it will be the first object of our investigation to determine. These will depend partly on the elevatory forces, and partly on the resistance opposed to its action by the cohesive power of the mass. Our hypotheses respecting the constitution of the elevated masses, are by no means restricted to that of perfect homogeneity; on the contrary, it will be seen that its cohesive power may vary, in general, according to any continuous law; and moreover, that this power, in descending along any vertical line, may vary according to any discontinuous law; so that the truth of our general results will be independent, for example, of any want of cohesion between contiguous horizontal beds of a stratified portion of the mass. Vertical or nearly vertical planes, however, along which the cohesion is much less than in the mass immediately on either side of them, may produce considerable modifications in the phenomena resulting from the action of an elevatory force. The existence of joints, for instance, or planes of cleavage, in the elevated mass, supposing the regularly jointed or slaty structure to prevail in it previously to its elevation, might affect in a most important degree the character of these phenomena. To a mass thus constituted, these investigations must not be considered as generally applicable."³

After a very clear summary of the mathematical results of the investigation, first as to a thin lamina acted on by one, two, or more systems of tensions, and, finally, to a mass of three dimensions, the author proceeds to apply these results to the actual case of a portion of the earth's crust, under the hypotheses respecting the action of the elevatory forces, and the cohesive power of the mass, which have been already stated.

1. *Longitudinal Fissures.* In the case of a mass of indefinite length, bounded laterally by two parallel lines, with the elevatory force uniform, the extension, and therefore the tension, will be entirely in a direction perpendicular to the length, so that its whole tendency will be to produce *longitudinal* fissures, or such as are *parallel to the axis of elevation*. These fissures will not commence at the surface, but at some lower part of the mass. The whole series of stratified rocks existing above an originating line of fissure, will be affected by the tension producing it; but under certain cases the fissures may not reach the surface. The width of the fissure will be nearly the same at all depths of disturbed strata (varying, however, with their elasticity). Any number of these fissures might be formed simultaneously, more, it is probable, in the deeper parts.

¹ *Geological Proceedings.*

² *Geology of Yorkshire*, vol. ii. p. 119.

³ *Cambridge Trans.* 1835.

Geology. Thus there are complete and incomplete fissures, all parallel to the axis of the uplifted tract.

2. *Transverse Fissures.* If the elevatory force be supposed to act with greater intensity at particular points along the general line of elevation, or an additional force *superimposed* on a uniform force, the axis of elevation will be undulated by one or more cross ridges and hollows; and parallel to these another system or systems of fissures may be produced, circumstanced like the longitudinal fissures previously mentioned, as to completeness, width, &c. but ranging across the *axis of elevation* and approximately perpendicular to the longitudinal fissures. This result is almost independent of time: the transverse fissures may be instantaneously following, or very long subsequent to the longitudinal fissures.¹

3. *Fissures of a Conical Elevation*, if produced solely by forces of great intensity and limited area, will commence along or very near to the axis of the cone, and be continued in a vertical plane, passing through the axis. If such forces were exerted *simultaneously* with those determining a general axis of elevation and fissures parallel thereto, the result would be a local convergence of such longitudinal fissures towards the axis of the conical elevation, beyond which they would resume their parallels. A contrary deviation of these fissures would follow upon a spherical elevation.

4. *Faults.* By the decrease of the expansive forces which produced the tensions occasioning the fissures, the equilibrium of the divided parts would be destroyed, and they might rest in unequal elevation above their original level, thus producing longitudinal and transverse faults. Anticlinal, synclinal, and simple faults are thus easily understood to be all consequences of the new positions taken by the divided rocks upon the cessation of the sustaining forces.

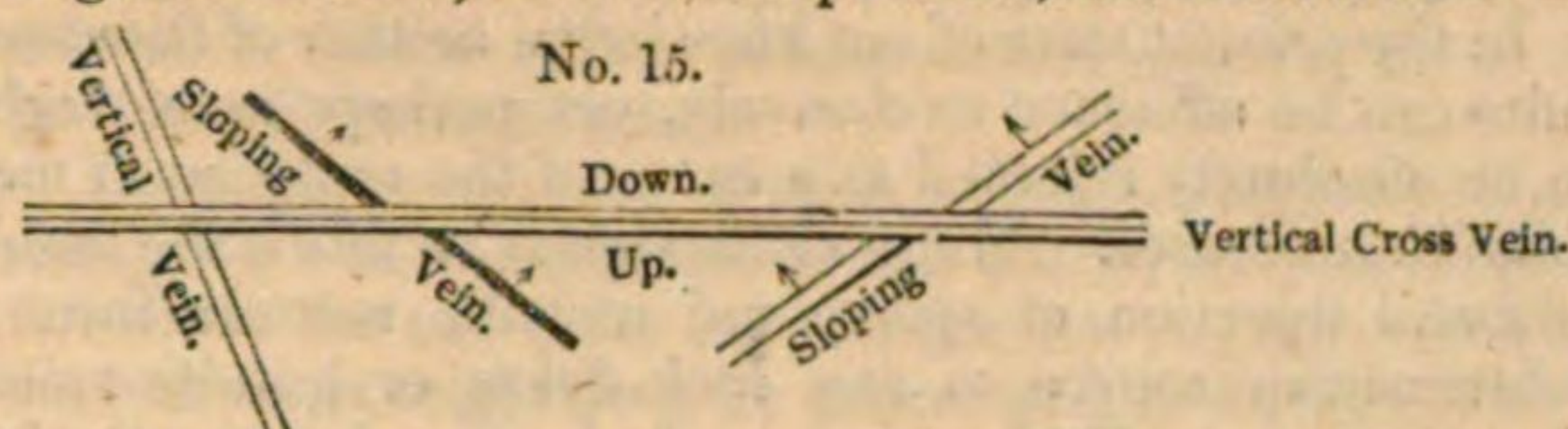
Without prosecuting further our abstract from Mr Hopkins' ingenious paper (which embraces, however, many other remarkable coincidences with observations), we may quote his important conclusion.

"If the approximate accuracy of our assumptions be allowed, as applied to the crust of the globe, it appears from our investigations that an elevated range characterized by continuous systems of longitudinal and transverse fissures, referrible to the causes to which we have been assigning such phenomena, could not be produced by successive elevations of different points, by the partial action of an elevatory force. In such elevations, fissures would necessarily diverge in all directions from the central points, so that parallel systems, such as have been mentioned above, could not possibly be thus produced. Every system of parallel fissures in which no two consecutive fissures are remote from each other, must necessarily have had one simultaneous origin."

ORIGIN OF MINERAL VEINS.

This has long been, and will for some time continue, a disputable question in geology; but considerable progress has been made in it since the days of Werner and Playfair. *The origin of the fissures* in which a great proportion of mineral veins occur, is certainly proved to be either by molecular attraction, causing contraction of the mass of rock, and thus generating joints or divisional planes, or by the tension of elevatory forces, as explained in the last section. *The relative antiquity* of the fissures constituting rake veins, (in Cornwall called lodes), is become a practicable problem, since Mr Hopkins has given mathematical deductions to aid the observation of facts. When, as is universally found

in a mining district, some veins as AB cross others as CD, (Diagram No. 15.) and interrupt them, the conclusions of



the miners have generally been in accordance with the Wernerian dictum, viz. that the continuous vein is of less antiquity than that which it divides; but Mr Hopkins thinks this conclusion untenable. For if the displacements of the veins be only apparent, that is, if either of the fissures has been originally formed with the irregularity in question, in consequence of any line of least resistance affecting the direction, it must be the newer CD, which has deviated along the fissure AB, and then resumed its bearing.

But if the displacement be real (whether vertically or horizontally), then, as far as relates to the fissures, they may be contemporaneous. It may, however, be possible from other considerations, to determine the relative epochs of the introduction of mineral matter into fissures, if not the geological dates of their production.

The differences of the contents of veins in a given mining region, *e.g.* Cornwall, appear certainly in a considerable degree related to their directions. Werner long since proposed a classification of veins founded on their directions and contents, and supposed it possible to refer even English mineral veins to their place in his Saxon Mining System from such considerations. (Werner on Veins, translated by Anderson.) Mr Carne gives no less than eight principal systems and ages of mineral veins in Cornwall. The criteria of age are founded on the displacements of the veins; east and west is the most prevalent line of productive veins; north and south of the cross courses, which are generally unproductive.

Repletion of Mineral Veins.—The opinion of the Cornish miners and geologists generally appears to be, that most or all of these veins are to be regarded as contemporaneous with the rocks which enclose them; but the arguments for this contemporaneity are not so satisfactory as those employed by Professor Jameson in the case of contemporaneous veins in igneous rocks.—*Wern. Trans.* Dr Boase and others, however, mention the change of metallic contents with change of rock,—the favourable or unfavourable character of certain rocks for yielding ore, &c.

Whatever force may be thought due to the facts and the opinions brought forward on the subject of veins in Cornwall, it is perfectly certain that, in distinctly stratified countries, the mineral matter has been introduced into open fissures long after the deposition and consolidation of the strata. *The proof is unanswerable.* Joints and fissures filled with metallic and sparry matters (mineral veins), pass through rocks which are not contemporaneous but successively deposited, and *divide corals, fishes, &c.*² It is evident that this must close the discussion as far as regards these rocks.

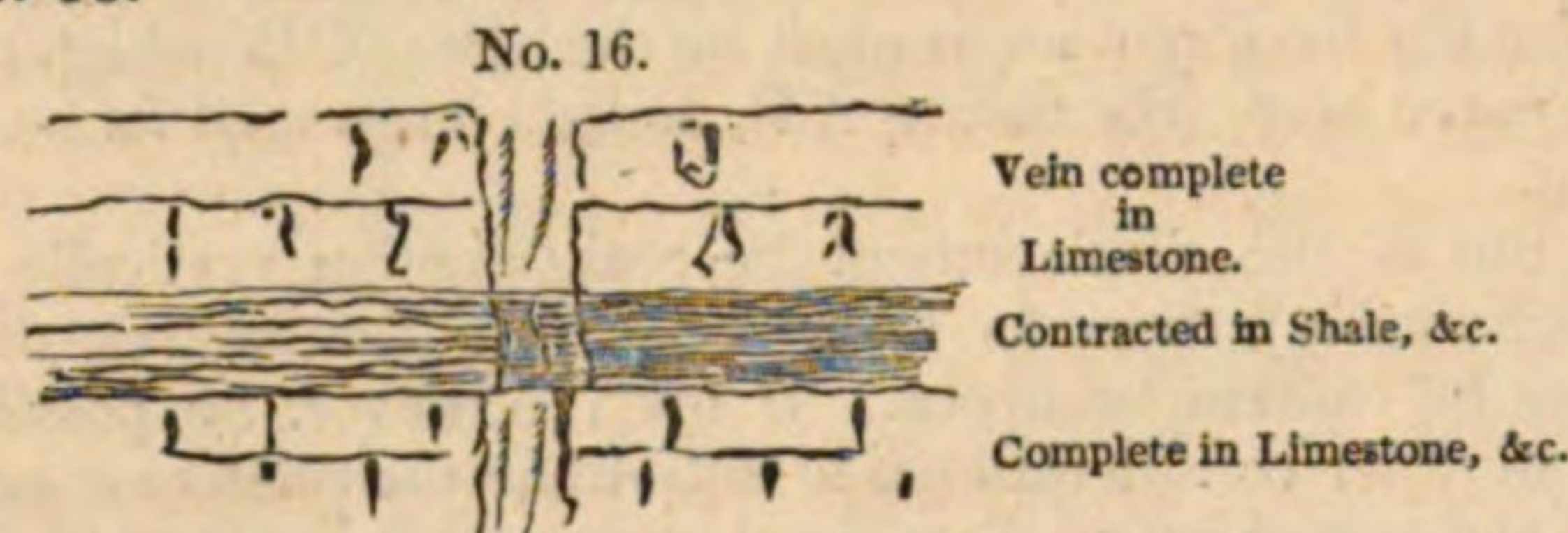
But, though it cannot be reasonably doubted, as a general truth, that the vein-stuff has been transferred into open fissures of the rocks, it is not so easy to determine how this was effected. Have the materials been injected from below as lavas into the fissures of a mountain (Hutton), or sublimed from a hot region to a cold fissure (Buckland), or segregated by some peculiar influence from the neighbouring rocks (Sedgwick), or poured into them in aqueous so-

¹ These deductions from theory are supported by many well established facts. ² Report British Association, Edinburgh Meeting.

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lution (Werner), or transferred by electrical currents (Fox), as in some instances we have good reason to believe?

In the present state of our knowledge neither of these results can be admitted exclusively, yet perhaps none ought to be absolutely rejected as a cause of the repletion of metalliferous fissures. Many veins appear as much the result of a real injection of sparry and metallic matters from a subterranean source as any rock-dykes or granite-veins. But when, as in Derbyshire, we find mineral veins divided horizontally by a particular stratiform mass, as toadstone, and in other parts by argillaceous beds, so that the vein, being a full fissure above and below, is only represented in the toadstone or shale by one or a few strings of calcareous spar, it becomes evident that injection is not the only cause of the repletion of mineral veins. See Diagram No. 16.



Sublimation from the heated subterranean laboratory of nature through the fissures of rocks is a very probable, but not universal, cause of the repletion of veins. It is probable because of the agreement between the successive vertical lamination of the materials of a vein and the supposed successive introduction of them to the fissures; but this is not conclusive, inasmuch as the processes of crystallization from a general fluid mass may as well be appealed to for producing the same phenomenon. It is not universal, because of the frequent occurrence of perfectly insulated nests of metallic and sparry matter in shells and in the substance of rocks. These, indeed, afford a very strong *prima facie* argument in favour of the collection by molecular segregation or electrical transfer of the different particles. If we consult general probability, it will appear most reasonable to admit these separate aggregations of metallic and sparry matter, as being laterally transferred from the vein rather than examples of segregation from the rock. Nearly every case of peculiar apparent relation between the sparry and metallic contents of a vein to the nature of the enclosing rock, vanishes on a careful scrutiny. It is not because of any peculiar chemical quality that limestone yields most lead-ore in Aldstone Moor, but because of its being a rock which has retained openness of fissure. Gritstones, in many mining fields near Aldstone Moor, are equally productive; but shales, as being soft extensible layers, have closed up the fissures, and their crumbling faces appear to have rejected the crystallizations which attached to the harder limestone, gritstone, and chert.

If any doubt could remain on this point, it is removed by the observations of Necker, Dufrenoy, Murchison, and others, as to the real and evident dependence of mineral districts, that is, districts where the rock fissures are full of valuable minerals, upon axes of disturbance and upliftings of igneous rocks. In the Pyrenees, in Brittany, in Cornwall, the Shelve district of Shropshire, Flintshire, Derbyshire, Yorkshire, Aldstone Moor, this important law is certain. Whatever be the chemical nature of the rock adjoining the dislocation or igneous rock, the productiveness of the veins is chiefly regulated by its condition as to fissures. Limestone in Derbyshire, millstone-grit in Nidderdale, chert in Swaledale, basalt in Teesdale, coal near Bradford, and Richmond, all yield sulphuret of lead and various associated sparry substances.

Prevalence of Mineral Veins in Rocks of different Age.

—As a general result, we cannot doubt of the far greater prevalence of mineral veins in the older than in the newer rocks. Not one case is known of a mineral vein being at

any time worked in any part of the British islands above the new red sandstone. In the new red sandstone and magnesian limestone hardly more than slight traces of such products occur; they are rare in our coal-tracts, but they become abundant in the mountain limestone and older strata. But yet it is probable that this relation of mineral veins to the age of deposits is merely a consequence of the more general truth, that their origin is from below, that the fissures which they occupy, and the metallic and sparry matters which compose them, are more numerous near the igneous rocks which in so many instances form the axes of movement. It is not merely because of the antiquity of the Killas of Cornwall, but of its proximity to granite rocks, that it is so very metalliferous; the limestone of Ireland, undisturbed by great axes of movement, is very little metalliferous; while the same rocks dislocated in Mendip, Flintshire, Derbyshire, &c. yield many sorts of metals and spars, in veins of different kinds.

Thus, the most general point of view in which mineral veins present themselves, is that of dependence on proximity to the sources of subterranean heat. In the rocks nearest these sources they are most numerous and varied; they abound near the disturbances which are consequences of variation of internal heat; and, in certain cases, (Pyrenees, &c.), they are not rare even among newer strata where the subterranean igneous rocks have exerted a remarkable influence.

DESICCATION OF THE ANCIENT BED OF THE SEA.

The strata, with their organic contents, having been already proved to have formed in succession the bed of the sea, and the far greater part of the surface of the globe even to great heights in the Andes and Himalaya, the Alps, Pyrenees, Caucasus, and other mountains, it follows that nearly the whole terrestrial surface of the globe was formerly submerged, and has since been laid dry. The desiccation of the land is a problem of fundamental importance in geology, influencing a multitude of secondary inquiries. If we might venture to suppose the quantity of water upon the globe variable, the land might be imagined to have risen above the ocean in consequence of the great abstraction of the latter; but, in the first place, there appears no probability that such a supposition is admissible, even by bringing a comet in contact with the earth; nor does it agree with the observed condition of the strata. For these by no means appear in such arrangements as to correspond with what we know of the character of a large part of the stratified bed of the sea.

Dismissing, then, this notion, and restricting ourselves to the conditions of sensible constancy in the quantity of water upon the globe, we find the problem of the desiccation of the bed of the sea reduce itself to the determination of the causes of the change of relative level of land and water.

Such a change of relative level might happen in many ways, some with, others without, local changes in the form of the solid parts of the crust of the globe. To the last class may be referred variations of level arising from change of temperature or alteration of the earth's axis of rotation. The former includes a variety of cases of subterranean movements.

EFFECTS OF VARYING TEMPERATURE NEAR THE SURFACE OF THE GLOBE.

Whatever be the constitution of the interior of the globe, a general change of temperature of the whole mass of land and water must of necessity alter the relative level of land and sea, because the ratios of expansion and contraction of the solid and liquid parts are unequal. Water changes its dimensions in a higher ratio to the difference of tempera-

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ture than the rocks of the crust of the globe; hence a general cooling of the mass of the globe, or to a considerable depth from the surface, ought to cause the *ocean to sink* relatively to the land; on the contrary, with any augmentation of temperature the *ocean would rise* upon the land. As sea-water contracts continually down to its freezing point, and the greater part of the ocean never freezes, we may, by assuming a probable mean depth, arrive at some useful results. If the mean depth of the ocean be taken at ten miles, which is probably too much, though nothing is positively known, and it be supposed to have cooled from a boiling heat to a mean temperature of 40° F., its change of volume would be about $\frac{1}{1000}$. The corresponding cubical contraction of the land, supposing it to have the rate of expansion in glass, would be about $\frac{1}{1200}$. If the areas of the surfaces of land and sea were supposed nearly to continue in the same proportion, the whole cubical contraction of the land and water would operate in lowering their level $10 \times \frac{1}{1000} - \frac{1}{1200} = 0.395$ miles, relative lowering of water-level. But this cannot be admitted; for the slopes of the land into the sea, over a great part of the globe, are very moderate. If the linear contraction of the water alone be taken, and compared with that of the land, we have the lowering of the ocean $= 10 \times \frac{1}{3000} - \frac{1}{1200} = 0.132$ mile $= 697$ feet.

When we consider the gently sloping surfaces of a large part of the land, we shall see that the contraction of the area of the ocean would diminish its linear depression, and upon the whole we cannot doubt that a fall of 697 feet is much beyond the amount that could possibly happen if the whole ocean had cooled from a boiling temperature to 40° Fahr. But this difference of level is too small to account for the desiccation of more than a small portion of the surface of the land; the hypothesis must therefore be abandoned as a general explanation, though hereafter it may be found of great importance in a more comprehensive theory.

GENERAL CHANGE OF DIMENSIONS OF THE GLOBE.

Let us now trace the effects of a general change of the dimensions of the globe on the relative level of land and water.

If we suppose the whole globe to undergo change of dimensions by variation of heat, the effects already ascribed to variation of temperature in the exterior part would still take place; but, in addition, would be complicated with an effect depending on the change of spherical area of the surface. In the case of augmenting temperature of the whole globe, the water would rise upon the land, as explained in the last section, but its rise would be less in that case, in consequence of its expansion over a larger area. If the expansion of the whole globe should go to such an extent as to change the diameter (D) into $D \times (\sqrt{1.039})$, or from 7900 to 8055 miles, the fall of the ocean would equal the rise of it due to the unequal expansion of land and water from 40° to 212° .

It appears, then, that the desiccation of land is not an effect of the general cooling of the globe, *without change of form*, for the effect due to that is of a contrary description; nor of the unequal contraction by cooling of the superficial parts of the globe, for that effect, even through the whole range from boiling heat (212°) to 40° F. would be totally inadequate to account for the phenomenon, even if the depth of the ocean be supposed far greater than it is admitted by astronomers to be.

Of the great physical events to which such a change of level may be ascribed, sound reasoning excludes all that are exterior to our globe; none of its relations to the sun and planets, none of the changes of these relations, are of importance in the matter. The only leading event really

influential on the point, which we may *imagine* possible, though astronomers give no encouragement whatever to the admission of it as a basis of speculation, is a change of the position of the earth's axis.

Upon the occurrence of such an event, there would evidently be a new disposition of the ocean; its waters would flow from the new poles towards the new equator, and some ancient lands might thus be submerged, and extensive surfaces laid dry.

The actual polar circles ought to be land; the equatorial zone should be deep sea. This want of agreement is remarkable; and, when we add to it the consideration that the absolute fixity of the pole of rotation, in a spheroid of revolution such as the earth is known to be, is a point supposed to be proved, we shall feel the necessity of abandoning altogether the attempt to explain the desiccation of the land, by imagining general depression, or partial abstractions of the ocean, without local *changes of form of the surface of the globe*.

CHANGES OF FORM OF THE SURFACE OF THE GLOBE.

Admitting such changes, the partial abstraction of the ocean may be viewed as a natural consequence, and the surface of the land may be studied, for the purpose of discovering the points of depression and elevation. We are thus brought back again to the observation of local phenomena, and may proceed by induction.

It is undoubtedly certain, by a large induction of examples derived from various geological periods, that mountain ranges and tracts of plain country have been raised by local elevatory forces. Anticlinal axes, parallel and rectangulated faults, are of a nature to prove the truth of this view. By such means, large breadths of land have been influenced, near and at considerable breadths from the axis of elevation. It further appears that still larger tracts of land, where no such evidence of violent and convulsive disruption of the strata occurs, must be supposed to have been gently and gradually lifted by an intumescence or expansion of the surface, depending on a continuous and very extensive subterranean agency. Thus, after the elevation of the Snowdonian chain, and the ridges of the silurian system,—after the Malvern and Abberley elevations,—the whole plain of the midland counties has experienced one general upward movement of a few hundred feet. Thus, the ancient vale of Eden has been raised since the rising of the Penine chain; and with it the whole area of the red sandstone round the Solway Frith, after the relative uplifting of the Lammermuir Hills. Instances of this double movement in the same physical region are almost universal.

That the elevation of the crust of the globe in one part was accompanied by depression in other parts, is extremely probable; but we cannot offer satisfactory proof from observation of more than local subsidences, and these generally complicated with subsequent elevations. The best case of such fluctuations known, is perhaps that of the emersion, submersion, and re-emersion of the Portland oolites, as indicated by the dirt-beds.

It is, of course, in the sea that we are to look for effects of subsidences, as the land gives those of elevation. To whatever extent we suppose such subsidences to have happened, and the level of the sea to have been thereby lowered, the phenomena indicative of a real elevation of the land are not less conclusive. This is a matter of calculation.

From Mr Hopkins's researches, it appears that the elevatory agency was of the nature of a gradually augmenting force, very extensive compared to the areas simultaneously disturbed. No example of modern earthquakes can be brought to render it probable, that mere volcanic agency could upraise the continents which it is capable of shaking.

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But if, for a moment, we abstract our attention from these limited developments of the energies of heat, and consider the elevatory action below continents and islands as the local resultant of diffused subterranean forces, it appears possible to arrive at a more general and equally applicable theory. If, as observations appear to indicate, the ocean once covered all or a large part of the globe, its mean depth must formerly have been less than at present: since the inequalities of the land arise from subterranean convulsions, and the bed of the sea is very irregular, we may admit that the whole or nearly the whole of the terraqueous area has been affected by local displacements. It is the resistance offered by the consolidated crust of the globe to a gradually augmenting *change of internal dimensions*, which caused the disturbing movements. We may therefore allow, that, before the production of a consolidated crust of the globe, the ocean (if it existed in a liquid form) was spread with considerable uniformity over the spherical surface.

From these postulates it must follow, that the actual bed of the sea has been formed by displacements, which, upon the whole, have caused a real subsidence; as the displacements of the land have, upon the whole, caused a real elevation of it. And our confidence in the assumed condition is augmented by observing, first, that they are all implied in the inferences from phenomena already adopted, and that they agree with the sentiment of astronomers as to the relation of the depths of the sea to the heights of the land.

REFRIGERATION OF THE GLOBE.

In endeavouring to embrace the phenomena of elevation and subsidence in one point of view, it appears almost immaterial whether we suppose the tension of the consolidated crust of the globe, which preceded its fracture and displacement, to have arisen from inward or from outward pressure,—from expansion of, or contraction upon, the interior nucleus,—because, in each case, the pressure would be of the general and gradually accumulating description required; but it seems an unavoidable condition *that the interior nucleus should be of a yielding nature*, to permit the subsidence of large portions of the surface, and accommodate itself permanently to the elevations. This condition leads us to the supposition of great interior heat, which, from general physical considerations, had before appeared very probable, and, from experimental researches, almost a matter of certainty.

If then, finally, we regard this heat as variable,—and, placed as the hot globe is in the vast cold regions of space, through which it radiates its uncompensated rays, it must be so—the globe must be growing cooler—we have at once the general physical cause of the phenomena of disruption and displacement on the crust of the globe, viz. *a collapse of this crust upon the internal nucleus slowly contracted by refrigeration*.

That this is the just inference from the principal laws of phenomena known in geology, we have no doubt; and we think it is free from any considerable objection. An obvious and plausible one is this: If the diameter of the globe be contracting through refrigeration, the length of the day, as compared to the length of the year, should vary and

grow less continually (the particles, which have a certain rotatory velocity, subsiding to describe circles of shorter radius). To which the answer is immediate and satisfactory, viz. that it is true, that, since the days of Hipparchus, the space of two thousand years has shewn no such variation; but that the conduction of heat through the consolidated crust of the globe is known to be so slow as to render that a very short period for the experiment; and further, that the crust does necessarily *not follow* in its contraction *uniformly* on that of the nucleus, but is for a long time in a state of tension, and is at last forced to accommodate itself to new dimensions by *a collapse*.

In corroboration of the doctrine of *a cooling globe*, we might here quote the phenomena of ancient organic life, which certainly agree with it, so far as to shew that vegetation of a tropical character, corals, and other zoophyta, crocodiles, and other reptiles analogous to the animals of hot climates, formerly inhabited the land and sea near the polar circles; and indicate that the surface of these now cold zones was then of a temperature explicable only by a greater heating influence communicated from within the earth.

The most complete test of this theory would doubtless be the deduction of phenomena from it: but this, in the present state of knowledge of the disturbed stratification of the globe, and other associated circumstances, cannot be usefully attempted, unless in the very general expressions of Leibnitz, who, after enumerating the leading features of the changes supposed to be effected in and on the cooling globe by fire and water, states its present condition as one of less unstable equilibrium,—“*Donec, quiescentibus causis atque æquilibratis, consistentior emergeret rerum status.*”¹

SUCCESSION OF ORGANIC LIFE ON THE GLOBE.

Man, placed at the head of the last great system of organic life which has been created on the globe, finds innumerable monuments of more ancient systems of being, fitted to earlier conditions of the planet he inhabits. Guided by the principle of adaptation of organic life to physical conditions, which, at every point of the earth and sea, is found now to obtain, and which, were it not discoverable by observation, might be surely inferred from the wisdom and general beneficence of creation, human reason is capable, to a considerable degree, of penetrating within the mysterious veil of antiquity, and restoring the terraqueous conditions of many former periods. Yet, as the perspective of long past time lengthens, the clearness of the picture fades away, and the dim and doubtful light disappoints our further scrutiny. Among the subjects which it is possible partially to illustrate by this investigation, are the relation of former systems of organization to that which is contemporaneous with the human race,—the relations of these one to another,—the creation of the several classes of animals, with reference to their place in the economy of creation.

The relation of former systems of organic life to that which is in activity around us, is of a peculiar description, full of general agreement and innumerable differences. The system of organic life, is perhaps, properly speaking, *one* from the earliest epoch to the present hour; for all fossil organization is reducible to the leading divisions of modern nature: and it is this only which allows us to include the existing animals and plants of distant regions as parts of one general arrangement. Fossil, as well as recent, plants are agamous, cryptogamous, or phanerogamous; the same

¹ See Conybeare, *Report on Geology to British Association*, 1832.

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leading divisions of zoophyta, mollusca, crustacea,—many of the same sections of fishes and reptiles, as those which we now behold,—occur in various ancient series of stratified rocks; and this is as much as can be said for the unity of the existing creation, dismembered as it is in different and distant lands and seas.

But when we come to examine minutely the degree of similitude among the correlative parts of those systems, great discrepancies appear. Groups and families of animals now hardly known, or very limited in number, appear predominant in several ancient strata; as, for instance, the brachiopodous and cephalopodous mollusca, large sections of radiaria, particular tribes of crustacea, polyparia, &c. Others, which contain but a few small species in the present economy of nature, are found to have numbered many and gigantic forms in older nature (as the saurian races, salamanders, &c.): the same is true with respect to the vegetable world.

The general result of the whole investigation may be thus expressed and paralleled. The organic forms imbedded in the earth exhibit less and still less agreement with those of existing races, in proportion as they belong to periods further removed from the present: just as, in modern nature, the differences between the productions of one country and another are, in several instances, distinctly proportioned to the distance between them; and just as, in the present system of nature, we see a mixture of agreements and differences between the productions of even remote regions; so, on comparing fossil and living tribes, the differences are found modified by various agreements. Extinct genera, as *producta* and *spirifera*, lie buried with existing genera, as *lingula* and *terebratula*, in the ancient mountain limestone. *Ammonites*, *hamites*, and *belemnites*, and other perished forms of life, are mingled, in the chalk, with *nautili*, *pectens*, and *echinodermata*, congenerous with those now in the sea. So with regard to plants. Extinct *lepidodendra* and *stigmariæ* lie confused with forms extremely analogous to existing tribes; and crocodiles, like the modern gavia, lived in waters the same or neighbouring to those which nourished the *ichthyosaurus*, *plesiosaurus*, and the other almost fabulous monsters of the reptile class.

From these, and a thousand other concurring facts, we venture to present the following conclusion. The organic remains of the different stratified rocks are those of creatures suited to the then conditions of the land and sea respectively; and because those conditions had some general features of agreement with what we now behold, a resemblance to this extent obtains between the fossil and recent creations; but, because of the numerous differences in physical condition, all the details of the organizations differ; and this disagreement is unequal in the different races, because of original inequalities, or their capability of accommodating themselves to new circumstances. This law appears also to be true in the present economy of creation.

On comparing the different systems of strata one with another, and with the present scheme of creation, the same law holds; and we find, in addition, the differences between the organic contents of one system and another, to be in proportion to the interval of geological time elapsed between them. Thus the fossils of the silurian system may be said to differ from those of the mountain limestone specifically,—from the oolitic system generically,—from the tertiary system, even by whole groups and sections of animal forms. This dependence on time, however, is a coincidence merely, as the analogy of fossils in rocks of analogous composition though different age, is sufficient to prove; the real dependence is on the *change of physical conditions, produced during the lapse of time*.

The present creation, and all the former effects of the Divine will, exhibits a series of beings destined to perform

unequal parts in the economy of nature. Some, as plants, are almost passive; others, as animals, perform the functions of active life. Man reasons,—inferior animals obey their instincts. Thus arises a peculiar scale of organization, in which the places of the different living tribes may be marked, with reference to their supposed degree of importance or excellence; and the races of the animal kingdom, in particular, are said to be of higher or lower grade, in proportion to the complexity of their organization, and the variety of their sensations and actions. What is the order of succession of these beings thus reckoned to be inferior and superior? Is the earliest organization known to us, remarkably inferior in complexity to that we now behold? These questions have been frequently proposed, and sometimes answered by an erroneous assertion instead of candid and impartial investigation. The most popular notion appears to be, that as man is undoubtedly the highest type of the last creation of animal life, all the former ones should be viewed as gradually ascending step by step from the inferior tribes towards the point of ultimate perfection; that the several classes of animals, in the ratio of their rank in creation, should successively appear; the inferior order of forms being found in the lowest and most ancient order of strata.

There is some truth in this. Mollusca occur in the lowest of all the systems of fossiliferous strata (Snowdon); zoophyta, mollusca, crustacea, abound in all those above the lower series. Fishes appear in the silurian rocks; reptiles in the red sandstone; birds in the oolites; cetacea, mammalia, &c., in the supracretaceous beds. But on looking carefully into the matter, it is found capable of a different construction. The fossils are mostly of marine origin; hence the rarity of insects, birds, and mammalia. On the bed of a modern lake, how few bones remain to inform us of the ancient finny inhabitants. The rarity of such remains is remarkable among all the strata, not excepting even the lias; and yet we find, in the silurian rocks near Ludlow, a whole bed of fish-bones and scales, just as in the lias of Westbury. (Mr Lewis of Aymestry.) The order of occurrence of vertebral reliquiae is generally fishes, reptiles, birds, and mammalia; yet the occurrence of one genus of didelphoid quadrupeds in the oolite of Stonesfield, is a formidable exception; and the general absence of all land animals from the marine strata, offers an escape to those who totally deny this successive production of the classes of animals, according to their grade of organization.

Neither is the order of occurrence of marine reliquiae such as to afford much countenance to the notion of gradual improvement in organic life. The classes of mollusca are more ancient than those of zoophyta, if we trust our present knowledge, and both older than marine or land plants,—a seeming paradox, since the pre-existence of vegetables seems capable of being sustained by strong arguments drawn from the relations of animal and vegetable life.

But we may contemplate the question as to the gradual improvement of animal organization in another point of view. Instead of comparing class to class, let us compare those of one group but different geological age. The bivalve mollusca of the oldest Snowdonian rocks were certainly as complicated, nay, more highly organized than the greater number of conchifera of the present ocean, since they belong to the brachiopoda. The crustacea of the silurian system were at least as curiously organized as the limuli of the North American coasts. The goniatites of the mountain limestone are far more curiously constructed than the nautili which lie with them, and also inhabit modern oceans. The belemnites and ammonites, turrilites and other extinct genera of the oolite and chalk, reveal to us an extinct order of cephalopoda, larger, more powerful, and more curiously organized, than existing loligines and sepiae.

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It is evident, therefore, that the whole notion of a gradual amelioration or enrichment of the animal organization may be dismissed as a mere illusion of the fancy of a finite being, who vainly transfers to the work of the Almighty the pattern of his own limited labours.

The systems of organic life have always been adjusted to the actual conditions of the land and sea. When water covered the globe, life was marine; as land arose, and new conditions supervened, terrestrial life was created; old races died away; with new circumstances, new creations were called into being to supply their place; and at length the physical revolutions of the globe brought that wonderful variety of external circumstances to which organic life is at this day adjusted.

Thus a perpetual stimulus is afforded to man, the last great creation of Divine power, to study the works of his Maker, and through them to receive proofs "strong as Holy Writ" of the long-enduring providence of the Almighty, whose appointed plans the permitted violence of the physical agencies of nature, amidst all their irregularities, exactly fulfil; and whose care, now so manifest for his human creatures, has never been withheld from the meaner forms of every age since the time when the earth became tenanted by beings capable of enjoying their own existence.

GEOLOGICAL TIME.

The chronology adopted by geologists is liable to an inherent uncertainty or indefiniteness, quite different in its nature from the sources of error in ancient history. In the history of human affairs, the whole period which elapsed between the two epochs chosen as limits is known or supposed to be so; but the intervening occurrences cannot often be correctly placed in their true succession. In geology, on the contrary, the whole period included between the limits is, and perhaps must ever be, absolutely unknown; yet the succession of occurrences is, in general, clearly ascertained. Again, it frequently happens, that the histories of different nations have no common features for very long periods, but remain insulated. This defect is less sensible in geology; for some of the monuments of contemporaneous physical conditions of the globe are very widely diffused.

The true scale of geological chronology is that of the stratified rocks. According to the view previously advocated, the several systems of strata mark periods more or less exactly definable; the last, or supratertiary period, which descends to the present era of the globe, being, as yet, one of the least defined in its limits.

It has been already explained that historical time, commencing with the human race, is not yet united to geological time. Whenever the exact place of the creation of man, on the scale of geological phenomena, can be fixed, and the two scales continuously united, we may be able to advance, without certainty of utter failure, to the consideration of the problem lately proposed for a prize essay by the Royal Society of London, viz. the translation of geological into astronomical periods.

At present the chronology of the globe, starting from the origin of the stratified rocks, and including the whole series of successions of organic beings, and all the convulsive disturbances of the cooled and consolidated crust, recognises many successive periods of unknown duration. Neither does it appear possible to know their duration, or even the limits of error within which they fall. How, then, it may be asked, do geologists justify their confident assertions of the very great antiquity of particular rocks as compared with the few thousand years of history? To this the reply is simple. Many of the ancient stratified rocks were formed in the sea by processes perfectly similar to those which go on at this day; and, in some cases, we

may believe not at all more rapid in their effects. The laminated sandstones often mark what appears to be the ripple of a gentle tide, and the successive deposits of agitated water; the shelly limestones sometimes prove very slow deposition of even a single layer of calcareous rock; the alternation of igneous and sedimentary rocks gives us the similitude of volcanic submarine eruptions. Now, if we compare with the sedimentary strata of any particular period the most similar products of the present day,—the new land on the Adriatic,—the filling up of the Nile Valley,—the shallowing of the Bay of Bengal,—we shall be impressed with the necessity of allowing a long period for the production of a single stratified formation.

Again, if we recollect, that during these periods many creations of new and destructions of old races of animals and plants happened,—and that, ever since the records of human art, the embalmed body or sculptured effigies, have given the means of judgment, no change has happened to modern races; that two or three thousand years have not changed the forms of animals known to the early Egyptians; we shall see the impropriety of imagining such changes to have been of quick succession in the earlier eras of nature.

And when we behold conglomerate rocks which hold fragments of other earlier deposits, and, in these fragments, the organic remains of still earlier periods which had already undergone their peculiar mineral changes; when we collect the history of such an organic form,—its existence in the sea,—its sepulture in a vast oceanic deposit of limestone, or in a littoral aggregation of sandstone,—the induration of this rock,—its uplifting by subterranean forces,—the rolling of it to pebbles,—the reunion of them in a totally different kind of substance,—it is evident that no greater folly can be committed than to think to serve the cause of truth by contracting the long periods of geology into the compass of a few thousand years.

The task of reducing these long periods to any definite scale, is at present entirely hopeless. Three possible modes seem open to us; but we cannot advance a step in any one of these, without immediate aid from visionary and delusive guides.

1. Could we know the rate of secular refrigeration of the globe, either from general physical considerations, or a summation of the effects of convulsive movements, a basis of inquiry would be established. But who will dare to attempt the solution of such a problem?

2. Could we know the mean or extreme rate of production of stratified deposits at the present day, this would enable us to conjecture the lengths of some geological periods, and with double hazard refer others to this conjectural scale; but even this unsatisfactory estimate would be liable to the further and fatal error of not knowing the ratio of the forces in the different periods. To assume this ratio is only to augment in a still higher degree the amount of improbability.

3. Perhaps the safest, certainly the most alluring, of the three methods which geology may follow in this dark research, is that which is founded on a strict scrutiny of the history of organic remains. The life of animals and plants is a phenomenon distinctly related to annual periods; and, for some systems of strata, as for example the tertiary, the resemblance of specific forms is enough, the great number of coincidences being considered, to authorize deductions as to the length of life of fossil and recent species of marine mollusca. But here the want of knowledge is utterly fatal. Who can tell us the average term of life of marine molluscan animals, sufficiently comparable with tertiary shells, to form a basis of good reasoning?

It is evident that we have no knowledge capable of being employed, in the magnificent problem of the age of the crust of the globe, at all equal to the difficulty which meets

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Minerva
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us on the very threshold. Until the constants of nature which relate to the dependence of organic or inorganic phenomena on annual periods be known, the determination of the antiquity of any of the marine stratified rocks must be despaired of.

GENERAL RESULT.

We have thus briefly presented some fundamental inferences which must be embodied in any rational theory of geology.

To combine these and other sound inferences is the true business of theory: it ought not yet to be attempted; for

though the notion of a slow decrease of the heat of the globe being the primary law of causation, is perhaps continually forcing itself on the attention of geologists, as well calculated to account for the consolidation, disruption, and irregularity of elevation of the crust of the globe, and almost necessary to explain its actual condition of sensible equilibrium; though it is inconsistent with no astronomical, mechanical, or chemical truth, and meets without difficulty the problems suggested to zoology and botany by the monuments of ancient organic life; still the development of this truly general theory requires a far more exact survey of the structure of the globe, and a far more intimate acquaintance with the effects of modern terraqueous agencies, than we now possess. (H.)

Minervalia
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Mines.

MINERVA, or PALLAS, in Pagan worship, the goddess of science and of wisdom, who sprung completely armed from Jupiter's brain. She disputed with Neptune the honour of giving a name to the city of Athens, upon which it was agreed, that whosoever produced what was most useful to mankind should have the advantage. In consequence of this compact, Neptune, with a stroke of his trident, formed a horse; and Minerva caused an olive to spring from the ground. The latter was judged the most useful, from its being the symbol of peace. Minerva changed Arachne into a spider, for pretending to excel her in making tapestry. She fought the giants; favoured Cadmus, Ulysses, and other heroes; refused to marry Vulcan, choosing rather to live in a state of celibacy; deprived Tiresias of sight; turned Medusa's locks into snakes; and performed several other exploits. Minerva is usually represented by the poets, painters, and sculptors, as com-

pletely armed; with a composed but agreeable countenance, bearing a golden breastplate, a spear in the right hand, and an ægis or shield in the left, upon which is represented Medusa's head encircled with snakes; whilst her helmet was usually entwined with olives. She had several temples both in Greece and in Italy. The usual victim offered to her was a white heifer, never yoked; and the animals sacred to her were the cock, the owl, and the basilisk.

MINERVALIA, in Roman antiquity, festivals celebrated in honour of Minerva, in the month of March; at which time the scholars were indulged with a vacation, and usually made a present to their masters, called from this festival *Minerval*.

MINERVINO, a city of the kingdom of Naples, in the province of Bari, on the declivity of the Apennines. It is the seat of a bishop, and has a cathedral and three other churches, with about 6000 inhabitants.

M I N E S.

MINES (in Greek *Μεταλλαι*, and in Latin *Fodinæ Metallicae* or *Metalli Fodinæ*) are pits dug deep in the earth, whence are drawn the metals, the demi-metals, and other mineral substances, such as coal, rock-salt, alum, and the like. The excavations from which stones are obtained, however deep these may be, are denominated *quarries*, and not mines.

I.—ANCIENT MINES.

Scripture ascribes the discovery of brass (or copper) and iron, at least that of the methods of working them, to Tubal Cain, who lived before the Flood. But ere these metals could have been subjected to the skill of the antediluvian artificer, the metalliferous ore must have been extracted from the earth, and subjected to some metallurgic process, however rude; in other words, the invention ascribed to Tubal Cain implies the previous existence of mines and mining. This, however, has occasioned some perplexity, and produced considerable speculation as to the causes, whether accidental or other, which led to the discovery of mines. The method of discovering these is still a matter of so much difficulty, that it cannot but appear surprising, how men totally unacquainted with the nature of metals should first have come to think of digging them out of the earth in the shape of ore, and then applying heat to disengage them from the extraneous matter with which they have almost always been found combined.

According to the prevailing opinion of the ancients, this discovery was made by accident. Lucretius describes it as the result of the burning of woods or forests, which, melting

the veins of metals in the earth over which the conflagration passed, revealed to men the existence of substances previously unknown, and also indicated the method by which these might be converted into a state capable of being applied to useful purposes. Aristotle, who is of the same opinion with Lucretius, informs us, that some shepherds of Spain set fire to the woods, in consequence of which the earth became heated to such a degree by the flames that the silver near the surface melted and flowed into a mass, which was afterwards discovered in a fissure occasioned by an earthquake. The same story is told by Strabo, who ascribes to this accident the discovery of the silver mines of Andalusia. Cadmus, who first introduced letters into Greece, is said to have been also the original discoverer of gold; but this has been contested by some mythologists, who attribute the honour of the discovery to various other fabulous personages; as Thoas of Thrace, Mercury the son of Jupiter, and Pisis a king of Italy, who, having left his native country, and gone into Egypt, was elected king of the latter after the death of Mizraim, and, on account of this alleged discovery, was denominated the Golden God. The discovery, not only of gold, but also of all the other metals, is by Æschylus attributed to Prometheus, whose story, clouded as it is by fable and romance, seems to countenance such a supposition. The copper mines of Cyprus were originally discovered by Cinyra the son of Agryopa; and Hesiod ascribes to the Dactyli Idæi the discovery of the iron mines of Crete, the modern Candia. According to several ancient authors, the invention of the method of extracting tin from its ore was made by Medacritus, in the islands of the Cassiterides, and by him communicated to the natives. It is highly probable, indeed, that these and all other similar

Mines. discoveries or inventions were the result of accident rather than of research or investigation. Chance disclosed the hidden treasure, and a happy thought enabled some shrewd observer to turn the casual disclosure to account. Even in modern times, we know that many mines have been discovered in this manner; as, for example, in sea-cliffs rent by the violence of the waves, amongst broken and craggy rocks, by the washing of the tide or by floods, by torrents of water issuing from hills or mountains, by the wearing down of roads, and sometimes by volcanic eruptions. The ingenuity of man consists in taking advantage of those occasions when either nature or fortune puts it in his power to extend his knowledge, or to add to his wealth and comfort.

Our information respecting ancient mines is, we regret to say, extremely scanty and imperfect. The subject has not been specially treated of by any ancient writer with whose works we are acquainted; and the detached notices which occur in the classical authors have not received that anxious and critical examination which is indispensably requisite in order to arrive at just and accurate conclusions. To the general truth of this remark, however, there is one distinguished exception, in Boeckh's *Dissertation on the Silver Mines of Laurion*, appended to his very learned and interesting work on the *Public Economy of Athens*. In a short compass, all that can be gleaned from the ancient authors has been carefully brought together, and treated with a degree of critical ability which has enabled the author to throw much new light upon a subject that had almost entirely escaped the researches of preceding inquirers.

The mines (*μεταλλα*) belonging to the state of Athens were partly native and partly foreign. But the most considerable were the silver mines of Laurion, from which the nation derived no ordinary advantages, since, by the resources which they supplied, Themistocles first raised the naval power of Athens to a state of consequence and efficiency. These mines extended from coast to coast, in a line of about seven English miles, from Anaphlystus to Thoricus. The working of them had been commenced at an early period, and appears to have been very profitable in the time of Themistocles; but they became less productive in the age of Socrates and Xenophon, and before that of Strabo they had been so entirely exhausted, that all further mining was discontinued. The ores extracted contained silver and lead, with zinc, and probably copper, but no gold, or at least not enough to allow the ancients, with their imperfect processes of separation, to disengage it with profit. At Thoricus spurious emeralds occurred in combination with the ore; cinnabar was also found there, and occasionally a substance which afterwards came to be much prized in dyeing. The mines were worked by means of shafts and adits, and whole masses were removed, so that supports alone were left standing. The processes of fusion carried on in the furnaces appear to have been the same as those employed in the other mines which were worked in ancient times. The state was the sole proprietor of the mines; but they were never worked at the public expense; nor did the state ever let them for a term of years, like other landed property. They were always granted to private individuals in fee-farm; and these leases were transferred from one person to another by inheritance, sale, and other kinds of legal conveyance. The sale of the mines, or rather of the right of working them, was managed by the *poletæ*; and this right was purchased at an appointed price; in addition to which the possessor paid the twenty-fourth part of the net produce as a perpetual tax. The purchase-money was paid directly to the state, but the contingent rents were very probably let to a farmer-general. The amount of the money obtained from both sources necessarily depended upon a variety of circumstances, such as the number of

Mines. mines let in the course of the year, the comparative richness or poverty of the veins worked, and the degree of activity with which the business of mining was carried on. When Themistocles proposed to the Athenians to apply the funds obtained from the mines to the building of ships, instead of dividing it as before amongst the people, the annual receipts appear to have amounted to thirty or forty talents, although the accounts relating to this point are extremely indistinct and uncertain.

Citizens and isoteles were alone entitled to the possession of the mines. The number of the possessors was evidently considerable, and, like the agriculturists, they were considered as a separate class of producers; sometimes they possessed several shares, sometimes they had only one. The common price of a single share was rather more than a talent; and occasionally several partners occur as the joint possessors of a mine. The manual labour was performed by slaves either belonging to the possessors of the mines or hired from others; but although the cheapness of their labour diminished the expenses of mining, the improvements of art in facilitating or abridging the processes of labour were necessarily retarded. The security of this species of possession was guaranteed by severe laws, and the rights of the state were strictly maintained. There was a mining law (*μεταλλικός νόμος*), and a particular course of legal proceedings in cases relating to mines (*δικαι μεταλλικαι*), which, for the greater encouragement of the proprietors of mines, were in the time of Demosthenes annexed to the monthly suits. The mines were also free from property taxes, and did not subject the possessor to the performance of liturgies, nor were they transferred in the exchange (*ἀντιδοσις*) of property; immunities which did not arise from any wish to encourage the working of the mines, but were founded solely upon the particular nature of the tenure by which they were held. They were considered as public property let to usufructuary possessors in consideration of a fixed rate of payment, like the duties paid by the farmers; and no property, except such as was freehold, and exempted from rent or duty of any kind, subjected the holder to liturgies and property taxes.

That Athens usurped the possession of the mines belonging to her subject allies, cannot be assumed in conformity with the general system of her foreign policy; and we must suppose that these everywhere remained the property of the persons to whom they had belonged previously to the dominion of Athens. The mines of Thrace, however, appear to have formed an exception, and to have been immediately dependent upon Athens; indeed it is probable that they were let in the same manner as the Athenian mines, although we have no certain information on this point. The Thracian gold mines had been first worked by the Phœnicians, along with the mines of Thasos; and afterwards they were carried on by the Thasians of Paros. The gold mines of Scapte Hyle upon the mainland brought to the state of Thasos an annual revenue of eighty talents; those of Thasos were less productive, though notwithstanding they yielded a large sum. When the Athenians had established themselves in Thrace, they entered into a contest with the Thasians for the possession of the mines and harbours of the mainland; Cimon captured thirty-three ships in a naval engagement, besieged and reduced Thasos, and thus obtained for his country the coast, together with the gold mines. Scapte Hyle, and other cities of the mainland, were likewise conquered by the Athenians; but Boeckh conjectures that the gold mines were partly granted to the Athenians in fee-farm, whilst those of the ancient possessors remained in undisturbed occupation. If as many of the names of proprietors of the Thracian as of the Laurion mines had been preserved, we should have been able to speak with more certainty on this point; but the utmost extent of our knowledge is, that Thucydides possessed gold

Mines. mines in Thrace; and with regard to him it is doubtful in what manner he acquired such a property, the account most deserving of credit being that he obtained them by marriage with a lady of Scapte Hyle, whose predecessors had perhaps been long in possession of them.¹

Of all the metals, copper is that which is most frequently found pure in the ore; and for this reason probably it was also the first amongst them all that was wrought. This appears to have been the case in ancient Rome, where at first there was no coined money (*pecunia signata*), commodities being either exchanged by barter, or for a certain weight of uncoined brass (*æs rude*), used as a measure of value. To avoid singularity of expression, we use the word "brass" for what in reality was bronze, or copper rendered fusible by an admixture of zinc or of tin; a metal which was in general use, because masses of it were so easily transformed by fusion that nobody incurred loss by the process. The copper mines of Tuscany, especially in the country about Volterra, although now perhaps exhausted, appear to have been at one time immensely productive; and to this must be added the produce of the mines in Cyprus, now ascertained to have been enormous, and the influx of which into Italy is attested by the Latin name of copper (*cuprum*). The dependence of that island upon the Phœnicians in very remote times opened a way for this metal to the Punic markets; and Carthaginian vessels must have brought it into Italy. The low price consequent upon such plenty agrees with every thing that is known concerning the quantity of brass money, and its value in the times anterior to the introduction of silver money, which took place about the commencement of the first Punic war. In fact, it was long a remarkable and distinguishing peculiarity of the nations inhabiting the middle of Italy, that they employed copper or bronze in heavy masses, and not silver; whereas in the southern provinces, and along the coast as far as Campania, silver money was usually employed.²

Anciently Spain yielded an abundant supply of the precious metals, which her quicksilver served to refine. The Asturias, Galicia, and Lusitania, yielded, according to Pliny, twenty thousand pounds of gold annually. Silver was found in still greater quantities, and of the very best quality. "Argentum reperitur omnibus fere provinciis, sed in Hispania pulcherrimum," says Pliny;³ and from that country both the Carthaginians and the Romans appear to have derived immense supplies. It is even said that the single mine of Belbel yielded Hannibal three hundred pounds a day; and we further learn, that after Spain had been reduced to complete subjection by the Romans, these proud conquerors drew from it upwards of an hundred and ten thousand pounds of silver in the space of nine years, or at the rate of about twelve thousand four hundred pounds annually. Strabo also informs us, that neither gold, silver, copper, nor iron, were found in such quantities, or so excellent in quality, in any part of the known world, as in Turdetania.⁴

These notices of the ancient mines are no doubt scanty and meagre; but the want of precise information upon this subject, which is only adverted to in the most cursory manner by the ancient writers, renders it impossible to give any more ample or satisfactory account, either of the localities of the mines, the methods employed in working them, or the processes, rude enough no doubt, by which the metal was separated from the ore. Such being the case, we shall therefore take leave of this part of the subject, and proceed to give as ample details as our limits will admit, of the mines presently worked in Great Britain and

Ireland, upon the continent of Europe, in the republic of Mexico, and in the different states of South America. Mines.

II.—BRITISH MINES.

The mineral riches of Great Britain are immense, and, in some respects, superior to those of any other country. If it cannot boast of gold and silver mines, which are sometimes found in the poorest countries, it possesses a species of mineral wealth which is of still more importance to a manufacturing nation. It commands an inexhaustible supply of excellent coal, which is extensively diffused; its tin mines are the most productive of any in Europe; it has also very valuable mines of copper, lead, manganese, and other substances; and its salt springs, and strata of fossil salt, are alone sufficient to supply the whole world for an indefinite period. The most valuable minerals are situated in the western and northern parts of England, and in the southern and middle parts of Scotland. But the English mines are by far the most important, as will appear from subsequent details. In the meanwhile we shall commence our notices of the different minerals with that of coal.

1. Coal Mines.

It is scarcely possible to exaggerate the advantages which England derives from her immense beds of coal. In this climate fuel ranks amongst the principal necessities of life; without an abundant supply of it the country would be uninhabitable; and it is to the coal mines that we are indebted for a sufficiency of this indispensable article at a cheap rate. Nor is the advantage here stated the only one which we derive from these mines. They are the principal source of our manufacturing and commercial prosperity; and their products constitute the *materia prima* of our superiority in all the more extensive and important departments of industry. Since the invention of the steam-engine, coal has become of the highest importance as the means of generating the moving power; and no nation, if scantily supplied with this mineral, however favourably it may be circumstanced in other respects, can ever expect to rival those which are so, in most branches of manufacturing industry. To what else are we to ascribe the astonishing increase of Manchester, Birmingham, Leeds, Sheffield, in England, not to mention Glasgow and Paisley in Scotland, and the comparatively stationary or declining state of Canterbury, Winchester, Salisbury, and other towns, except to the abundance and cheapness of coal in the north, and its scarcity, and consequent high price, in the south? The citizens of Manchester, Glasgow, and the other places similarly circumstanced, are enabled, at a comparatively small expense, to put in motion the most powerful and complicated machinery, and to produce results which are altogether beyond the reach of those who do not possess the same command of this mineral. Coal has been happily defined "hoarded labour;" and it might, with equal justice, be denominated concentrated power. By means of it our manufacturers are supplied with a power of easy control yet of boundless energy, and are enabled to overcome difficulties insurmountable by those who happen to be less liberally supplied with this truly invaluable mineral.

It is uncertain when coal began to be first used as fuel, although, as early as the year 1281, Newcastle seems to have had some trade in this article. In the reign of Edward I. its

¹ Boeckh, *Public Economy of Athens*, vol. xxii. p. 18, 19, et seq. and 415, et seq.

² Niebuhr, *History of Rome*, vol. i. p. 398, et seq. Cambridge, 1828.

³ Pliny, *Hist. Natural.* lib. xxxiii. c. 4 and c. 6.

⁴ Strabo, *Geograph.* p. 194; Anstice's Essay, p. 11.

Mines. use was prohibited in London, on account of the smoke, which was supposed to be injurious; and afterwards this prohibition was renewed at different periods, but without any effect. But experience proved that the smoke was not deleterious; the growing scarcity of timber, and the superiority of coal as an article of fuel, secured its ascendancy; and since the reign of Charles I. it has become almost the only description of fuel which is used in the capital, and in most other towns and districts of the kingdom. Excepting in certain parts of Ireland and the Highlands of Scotland, where peat is employed as a substitute, its use is now nearly universal.

The consumption of coal in Great Britain is immense. It has been estimated at 15,580,000 tons annually, exclusively of exports to foreign countries; but this estimate, Mr M'Culloch thinks, is greatly under the mark. According to him, the consumption of Great Britain may be estimated at the rate of about a ton of coal for each individual, exclusively of the consumption in iron-works and other great branches of manufactures. This gives 16,500,000 tons for what may be denominated general or domestic consumption; although, to be within the mark, we shall take it at only 15,000,000 tons. If to this be added the quantities of coal consumed in the making of iron, the cotton manufacture, the woollen, linen, and silk trades, the smelting of copper ores, brass and copper manufactures, salt-works and lime-works, the total annual consumption of coal in Great Britain may be moderately estimated at upwards of 22,000,000 tons. Thus,

	Tons.
Domestic consumption.....	15,000,000
Production of iron.....	3,850,000
Cotton manufacture.....	800,000
Woollen, linen, silk.....	500,000
Copper and brass works.....	400,000
Salt-works.....	300,000
Lime-works.....	500,000
	21,350,000
Exports to Ireland.....	750,000
Ditto to foreign parts.....	600,000
	22,700,000

If we suppose that the above quantity, in which no allowance is made for the coal consumed in the manufacture of hardware and cutlery, costs the consumer at an average about seven shillings a ton, then 22,700,000 tons will be worth in all nearly eight millions sterling a year.

The importance of coal as a necessary of life, and an indispensable auxiliary in manufactures, has attracted attention to the question as to the probable duration of the supply, or the period when the exhaustion of the coal mines may be anticipated. But the investigations hitherto made as to the extent and depth of the different coal formations, and the degree to which they are capable of being worked, do not afford sufficient data for even an approximate solution of this question. Vague and unsatisfactory as they are, however, these inquiries leave no room for doubt that many centuries must elapse before posterity can experience any serious inconvenience from a diminished supply of this mi-

neral. According to Mr Taylor, the coal fields of Durham and Northumberland are adequate to furnish the present annual supply for seventeen centuries to come. The extent of these coal fields he estimates at 732 square miles. But, taking the workable coal strata at an average thickness of twelve feet, the contents of one square mile will be 12,390,000 tons, and of 732 square miles 9,069,480,000 tons; or, deducting one-third part for loss by small coal, interceptions by dikes, and other interruptions, 6,046,320,000 tons,—a quantity sufficient to supply the present demand of 3,500,000 tons for a period of 1727 years. It is evident that this estimate of the quantity of coal in Durham and Northumberland can be only a rough approximation, especially as the south-eastern coal district of Durham is yet almost unexplored, and there is also a considerable extent of coal field in the northern and south-western districts of Northumberland, which is nearly in the same situation; but it is sufficient to satisfy the public that no apprehension need be entertained as to this valuable mineral being exhausted for a great many generations to come. Dr Buckland, it is true, considers Mr Taylor's estimate as greatly exaggerated; but in his examination before the committee of the House of Commons, he quotes with approbation a statement in Bakewell's Geology, that the coal fields in South Wales are alone sufficient to supply the whole present demand for coal in England for a period of two thousand years to come.¹ Besides, in the west riding of Yorkshire, there are many extensive coal fields hitherto untouched. In Staffordshire, the coal strata are of immense magnitude, and the bed round Dudley is no less than thirty feet thick. In the present slovenly mode of working the coal, more than two thirds is left in the mine and wasted;² but were any thing like a scarcity of coal apprehended, this wasteful practice would be stopped, and means adopted for clearing out the contents of the mines. For all practical purposes, therefore, the supply of coal may be considered as quite unlimited.

The coal fields of Scotland are of great extent and value, indeed sufficient of themselves to furnish the whole empire with an adequate supply of this mineral for a long series of years. Coal is found in several districts of Scotland, as in Dumfriesshire and Roxburghshire, in the more southern counties; but the great field of Scotch coal stretches from south-west to north-east across the centre of the kingdom; and it is to be found in greater or smaller quantities in the counties of Haddington, Edinburgh, and Linlithgow, Stirling, Clackmannan, Kinross, Fife, part of Perth, Ayr, Renfrew, Lanark, Dumbarton, and part of Argyle. Its average breadth is thirty-three miles, and its length upon the mainland of Scotland ninety-eight miles; so that its total area is 3234 square miles. If from this we deduct 360 miles for the space covered by the Frith of Forth, there will remain 2874 square miles of territory, in most parts of which coal is found at different depths and of various qualities, whilst in about 600,000 acres of the same space it may be worked with advantage. The depth of coal varies, but in general it seems to be rather nearer the surface in the western than in the eastern division of the country. There is also a great variety in the number of its seams or strata, as well as in their thickness. The greatest thickness in the island is at Quarrelton, where five contiguous strata are upwards of

¹ The passage in question is as follows: "Fortunately we have in South Wales, adjoining the Bristol Channel, an almost exhaustless supply of coal and iron-stone, which are yet nearly unwrought. It has been stated that this coal field extends over about 1200 square miles, and that there are twenty-three beds of workable coal, the total average thickness of which is ninety-five feet; and the quantity contained in each acre is 100,000 tons, or 65,000,000 tons per square mile. If from this we deduct one half for waste, and for the minor extent of the upper beds, we shall have a clear supply of coal equal to 32,000,000 tons per square mile. Now, if we admit that 5,000,000 tons from Northumberland and Durham mines are equal to nearly one third of the total consumption of coal in England, each square mile of the Welsh coal field would yield coal for a hundred years' consumption; and as there are from 1000 to 1200 square miles in this coal field, it would supply England with fuel for 2000 years, after all our English coal mines are worked out." See also Treatise on the Collieries and Coal Trade, London, 1835.

² Bakewell's Geology, p. 183, 4th ed.

Mines. fifty feet thick. Seams less than eighteen inches are not deemed equivalent to the expense of working them.¹

Coal has been discovered in greater or less quantity in seventeen counties of Ireland; but the quality is in general bad, and, according to Mr Wakefield, "there is no vein of coal yet discovered in Ireland which can come into general consumption." Indeed, almost all the coal used in Dublin, Belfast, and other towns, is imported from England and Scotland. The principal coal districts of Ireland are those of Leinster, Munster, Connaught, and Ulster; the former districts containing carbonaceous or stone coal, the "slaty glance" of Werner, and the latter bituminous or blazing coal. The Leinster district is situated in the counties of Kilkenny, Queen's County, and Carlow, and extends a short distance into that of Tipperary, being the principal site of the carbonaceous coal. The Munster district occupies a very considerable part of Limerick and Kerry, and a large portion of Cork; it is by much the most extensive in Ireland. The Connaught district is next in importance to those of Leinster and Munster, and may perhaps be found to deserve the first place, when its subterranean treasures shall have been more fully explored. The coal, which is of the bituminous species, seems to be particularly adapted to the purposes of iron-works; and the gray pig-metal made at Arigna is reckoned to be as well smelted as any in the empire. The Ulster district, which is comparatively of trifling importance, commences near Dungannon, in Tyrone, and extends to Coal Island and the neighbourhood of Cookstown. Besides these districts, there are others of less consequence. Bituminous coal has been found near Belturbet in Cavan, and Ballycastle in Antrim; but the Antrim coal district is not very extensive, although the collieries have been wrought for a number of years. The coal is slaty, and resembles that which is found in Ayrshire, the accompanying rocks being likewise similar. These are all the coal districts of Ireland.²

Accidents in coal mines are very frequent, and arise principally from explosions of inflammable gas, but partly also from the presence of carbonic acid gas or choke damp, and partly from other causes. The returns of these casualties are by no means complete; yet, defective as they are, it appears from them that 2070 persons lost their lives in coal mines during the twenty-five years immediately preceding 1835. By an explosion which took place in one of the northern coal mines, more than a hundred men and boys were in a moment destroyed. In many instances not one of those employed in mines where explosions have occurred has survived to tell how the accident arose. Nor have the causes of these explosions, and the means of obviating them, been yet subjected to the continued or searching investigation of scientific men. During the eighteen years which have elapsed since the introduction of Sir Humphry Davy's safety-lamp, more explosions have taken place in the northern mines than during the preceding eighteen years. This, however, is ascribed not so much to the instrument having disappointed the expectations of the inventor, as to the fact that, by means of it, dangerous, or "fiery mines," have been wrought, which must otherwise have been long ago abandoned. But it has nevertheless been very clearly established that, in certain circumstances, especially when exposed to a current of air, the safety-lamp is no protection at all. In working the more dangerous, or "fiery mines," a vigilant and continued attention is required, which can scarcely be expected from ordinary workmen, and especially from boys; whilst, on the other hand, the smallest neglect may produce an explosion,

Mines. and occasion the instant death of hundreds. At present, it seems to be the opinion of the most experienced miners that efficient ventilation is the only thing which can be depended on. But as this indispensable security is, in many instances, too little attended to, it becomes a question whether the legislature should interfere, to the extent at least of prohibiting the working of "fiery mines," until they have been so ventilated that, with the exercise of ordinary precaution, imminent danger may be avoided. "It is useless," as Mr M'Culloch observes, "to trust any thing to the disinclination of the pitmen to engage in dangerous mines. By daily exposure to danger, they become habituated to, and careless about it; and, besides, they are apt to trust implicitly to the reports of *viewers* and others, who are quite as much interested in getting the coal brought cheaply to the pit mouth as in the security of the mine."

For details explanatory of the construction and the working of coal mines, and also of the machinery required for both purposes, the reader is referred to the article COLLIERY in this work.

2. Iron Mines.

Iron, which is one of the most useful, is also one of the most abundant of the metals. Of all minerals, indeed, it is the most universally diffused, and exists in every different state, the native alone excepted, in which metallic ores are found. Its presence may be detected in every kind of soil, and in every species of rock, in a greater or smaller proportion; and it is to be met with in every region of the earth. But the black or deep-brown oxides of iron, that is, the ores of iron which contain a large proportion of metal, combined with a small proportion of oxygen, belong exclusively to primitive rocks, of which they constitute an integral part; whilst, on the other hand, the ores of iron composed of the red oxide are generally found amongst secondary rocks, or, if met with in primitive rocks, exist only in veins, without forming a constituent part of these formations, as in the case of the black or deep-brown oxides. The primitive and some of the secondary rocks are the chief repositories of iron ores; but as to iron stones, they are found only amongst the secondary rocks, and sometimes also in alluvial soil. The ores of iron are richer, purer, and more abundant in the northern than in the southern regions of the earth. As there are few countries in the world which do not contain mines of iron, so in most of them some progress has been made in extracting the ores, and converting them to the various useful purposes for which this metal is above all others adapted from its peculiar qualities. But this double process can only be carried on to any extent, or with any degree of success, in those countries where fuel exists in almost equal abundance with the ore.

Iron has been wrought in England since the time of the Romans, by whom works were established in the Forest of Dean, in Gloucestershire. In Kent and Sussex, counties well supplied, not only with iron ore, but also with timber, the only species of fuel then used in the furnaces, works were also established at a very early period. But the production of iron was long retarded, from the nature of the fuel employed in smelting. Complaints were early made of the destruction of timber by the iron-works. In the reign of Elizabeth, the decrease of timber excited a great deal of attention; and, in 1581, an act was passed prohibiting the manufacturers of iron from using any but small wood, and establishing new works in any place within twenty-two miles of the city of London, and fourteen of

¹ General Report of Scotland, vol. i. p. 64.

² See Griffith's Report on the Leinster Coal District; and Phillips' Introduction to Geology, part i. p. 462.

Mines. the river Thames, as also in several parts of the county of Sussex. Soon afterwards, Edward Lord Dudley invented a process for smelting iron ore with pit-coal instead of timber, and obtained a patent for his invention, which was exempted from the operation of the act 21 James I. c. 23, setting aside monopolies; but the works of the inventor were destroyed by an ignorant rabble, and he was nearly ruined by his efforts to introduce and perfect a process which has eventually proved of immense benefit to the country. For many years, indeed, the invention seems to have been forgotten; and it was not till about 1750 that the growing scarcity of timber, coupled with the increasing demand for iron, succeeded in drawing the attention of some ingenious persons to Lord Dudley's process. Necessity is always the mother of art. This process was now revived; and, about the time mentioned, iron was made at Colebrookdale, and in some other places, by means of pit-coal, and proved to be of as good a quality as that made with timber. From this period the business steadily increased, though at first its progress was comparatively slow; and the great demand for iron occasioned by the late war gave an extraordinary stimulus to the manufacture, which has now become one of vast importance and great value. In 1740, the quantity of pig-iron produced in England amounted to about 17,000 tons, produced by fifty-nine furnaces. In 1750, it had increased to 22,000 tons; in 1788 to 68,000 tons, produced by eighty-five furnaces; in 1796 to 125,000 tons, produced by 121 furnaces; in 1806 to 250,000 tons, produced by 169 furnaces; and in 1820 to about 400,000 tons. From inquiries made by government and others during several years preceding 1832, it appears that the total quantities of iron produced in Great Britain in the years 1823, 1825, 1828, and 1830, were, in 1823, 469,561 tons, by 277 furnaces; in 1825, 618,236 tons, by 259 furnaces; in 1828, 703,184 tons, by 278 furnaces; and in 1830, 678,417 tons, by 376 furnaces.

Supposing that the total quantity of pig-iron produced in Great Britain amounts to 700,000 tons a year, and that at an average it is worth L.6 per ton, its total value will be L.4,200,000; and if to this be added L.1,200,000 for the labour expended in converting pig-iron into bar-iron, the manufacture will be worth about five millions and a half annually. The increased production of iron has led to its exportation in large quantities, and at the same time reduced the imports of foreign iron from about 34,000 tons to not more than 16,000 tons, consisting principally of Swedish iron for the purpose of being manufactured into steel. The total number of persons for whom the iron manufacture provides subsistence has been estimated at from 207,000 to 240,000.

The iron-works of South Wales and Monmouthshire are comprised in a range of country extending in the direction of north-west and south-east about twenty-five miles from the one extremity to the other. The works at Hirwain in Brecknock, and Aberdair in Glamorgan, form the extreme points to the westward. But the great seat of the manufacture is Merthyr Tydvil, from which there is a continued line of furnaces, at Dowlais, Romney, Tredegar, Howey, Beaufort, Nantyglo, Blaenafon, Varteg, Abersychan, and Pontypool, forming the principal range in that direction. About the middle of last century, Merthyr Tydvil was an insignificant village. In 1755, the lands and mines for several miles round the village, were let for ninety-nine years at a rent of L.200 a year. In 1831, the population of Merthyr Tydvil exceeded 22,000; Tredegar, which, at the beginning of the present century, was an uninhabited district, has now a population of about 7000 souls; and in several other places the increase has been equally rapid. The Staffordshire iron-works, including those of Warwickshire, are principally situated in the district which extends from Wolverhampton round by Walsall to Birming-

ham, and thence round by Dudley. The principal seat of the works in Shropshire is Colebrookdale, where the improvement of the manufacture commenced, as above stated.

In Scotland, almost all the iron-works, with the exception of those at Carron contiguous to the Forth, and at Muirkirk in Ayrshire, are situated upon the Clyde, at no great distance from Glasgow. In June 1835, there were in blast twenty-nine furnaces, the annual produce of which was estimated at 75,000 tons; but there were then in preparation six additional furnaces, calculated to produce 13,000 tons a year. The proprietors of the Clyde iron-works have recently begun to employ the *hot-blast*, or air heated to a high temperature, instead of the cold blast, or a stream of common atmospheric air, in working their furnaces; and this discovery (for some account of which see the article GLASGOW) promises to be of material importance, by economising fuel, and also improving the quality of the iron produced. It has been adopted at several works in England, as well as in France. Iron was formerly produced in considerable quantities in various parts of Ireland; but, owing to the scarcity of timber, the works were subsequently in a great measure abandoned. Attempts, however, have recently been made to revive them at Arigna and other places, though not as yet with any very decided success.

3. Tin Mines.

Tin is exclusively produced in Cornwall and in Devonshire, but chiefly in the former. The tin mines of Cornwall appear to have been worked from the remotest antiquity; in fact, those early navigators, the Phœnicians, are supposed to have traded thither for tin; and from this it has been inferred that the discovery of tin in Cornwall must have been made at least 2400 years ago. But it is supposed that the only ore then worked was *stream tin*, which is most accessible, and at that period probably existed in great abundance; nor is it probable that mining, or digging the ore from the veins, was known or practised until about the tenth century of the Christian era. In more modern times the business of mining has been prosecuted with various skill and success. During the reign of Elizabeth, the processes were improved by some German miners, who were brought over to assist in working the mines. The ores of tin are not numerous. It is chiefly found in the state of oxide, or in combination with other metallic ores, particularly that of copper. They are generally distributed in veins, which are at no great distance from the surface. The tin ore occupies the whole space of the vein, and is closely attached to the granite rock, which itself often contains the ore disseminated throughout its whole substance. Tin also exists in accumulated masses or *stockwerks*. The general direction of the veins is from east to west, or nearly so; and, if not interrupted or deranged by vertical strata, they preserve the same course in traversing a considerable tract of country. In some places tin and copper veins are united, and run parallel to each other; the tin ore forming one side, and the copper ore the other, of the double vein. The annual produce of the tin mines fluctuated a good deal during the last century. On an average of ten years ending with 1834, it may be taken at about 4500 tons, worth from L.65 to L.80 a ton. In 1834, the exports did not exceed 468 tons, the foreign market being principally supplied with tin from the island of Banca.

All tin produced in Cornwall is subject to a duty of L.4 per ton, payable to the Duke of Cornwall; and that raised in Devonshire is subject to a similar duty of L.1. 13s. 4d. per ton. This duty, which produces from L.15,000 to L.20,000 a year, is felt to be a serious grievance, not only

Mines. from its amount, but from the vexatious manner in which it is collected. The miner, whatever his orders may be, is not allowed at once to cast the metal into the form required by his customer, but is obliged, in the first instance, to melt it in the shape of *blocks*. He is then obliged to convey it some eight or ten miles to one of the *coinage towns*, where a small piece is struck off one of the corners, impressed with the arms of the duchy, and the duty paid; after which it has to be carried back before it can be shipped, to the place whence it was taken to be coined. The ceremony of coinage is only performed quarterly; and hence, if the demand for tin be ever so pressing in the interval between the stated coinages, the miner cannot supply it. There are likewise certain fees payable on coinage, particularly if it take place during the Christmas and Lady-day quarters; so that if to the duty of L.4 per ton be added these charges, and a reasonable allowance for expense of carriage, trouble, and inconvenience, the whole may be estimated at L.5 per ton. A tax at once so oppressive and vexatious cannot but prove detrimental to the working of the mines.

4. Copper Mines.

This metal is of much more importance than tin, on account of its tenacity, ductility, and malleability, as well as the numerous alloys and combinations which it forms with other metals, and which render it susceptible of being applied to many of the most useful purposes of life. It exists in almost all the different states of metallic ores, being found in those of native copper, alloy, sulphuret, oxide, and also in that of a salt. It is most abundant in Cornwall, where it is produced upon a very large scale, owing to the richness of the mines. These are in veins which traverse the country, frequently accompanying those of tin, and running in the same direction, which is generally from east to west. They are nearly in a vertical position, some of them being from four to five feet in thickness; and at a depth varying from 400 to 600 feet, they continue to be equally productive. The copper ores of Cornwall are chiefly yellow ore or iron pyrites, and vitreous copper ore; and they are commonly accompanied with other metallic ores, as those of lead, zinc, and cobalt, and also with fluor spar, lime spar, barytes, and quartz. Native copper is not an unusual production; it is generally found in that part of the vein which is nearest the surface, and which is the least rich in other ores. Sometimes, however, it is met with at a considerable depth, as in Cook's Kitchen Mine, which yielded several tons of copper fit for immediate fusion.¹ Malachite, and many of the varieties of arseniate of copper, are likewise found in these mines.

As the ores of copper and tin frequently occur intermixed, it may be supposed that the former were wrought, to some extent, at as early a period as the latter. But this does not appear to have been the case; and it is only since the beginning of the eighteenth century that the superior importance of the copper mines began to be understood, and that they were worked with spirit and success. From 1736 to 1745, they furnished annually about 700 tons of metal; and from 1756 to 1765 they yielded 1800 tons. In 1775 the produce increased to 2650 tons a year; in 1798 it exceeded 5000 tons; and at present (1837) it amounts to about 12,000 tons. Besides Cornwall, other parts of the kingdom supply considerable quantities of copper. The famous mines in Parys Mountain, in the island of Anglesey, were discovered in 1768. From the peculiar site and disposition of the mineral, it was not necessary to work it, like the Cornish mines, by shafts and levels, but to dig at once

Mines. into the sides of the mountain, which was composed chiefly of copper ore, and to extract it as if from an open quarry. The ore was obtained by blasting, and for a time the supplies of it were abundant beyond all precedent, forming a vast source of wealth to the adventurers and proprietors. But for many years past the productiveness of these mines has been declining, and they now yield comparatively little. The Parys Mountain is supposed to have furnished in all 85,000 tons of pure metal, which, at L.90 a ton, must have produced the enormous sum of L.7,650,000. At present the entire produce of the mines of Anglesey and Wales does not exceed 900 tons a year. Previously to 1770 the mine of Ecton, in Staffordshire, was one of the most productive in the kingdom. It is supposed to have been worked at a very early period, and at one time a thousand persons were employed in the works. The operations were latterly carried on at a depth considerably exceeding 200 fathoms.

From a statement published in the Transactions of the Cornwall Geological Society, and which appears to be authentic, we learn that the produce, in pure metal, of the copper mines of Great Britain and Ireland, during the five years ending with the 30th June 1827, that is, in 1823, 1824, 1825, 1826, and 1827, was, respectively, 9715, 9836, 10,350, 11,069, and 12,381 tons. Owing to the want of coal the Cornish copper ores are not smelted on the spot, but are shipped at the port nearest the mine for Swansea, where the principal smelting companies have their establishments. The copper produced in Ireland is also conveyed to Swansea to be smelted. Hence, if we take an account of the copper sold in Cornwall, at Swansea, Devon, and Anglesey, we shall obtain a pretty accurate estimate of the total produce of the different mines of the empire. But such an account has been furnished in papers published by the Board of Trade, containing the total sales of each year from 1820 to 1834 both included. From this it appears that the total produce of copper may at present be estimated at about 14,000 tons a year, worth from L.90 to L.100 a ton, or from L.1,260,000 to L.1,400,000. The exports amount to between 8000 and 9000 tons, partly wrought and partly manufactured, more than half of which is shipped for the East Indies and China, and the remainder for France and the United States. Copper is exempted from the tax laid on tin, and consequently from the oppressive regulations to which we have already alluded as growing out of it.

The number of the tin and copper mines of Cornwall is not exactly known, because old workings are frequently given up, and new ones opened, whilst, in many instances, those which were formerly abandoned are again brought into activity. The number of mines at present wrought, however, may be estimated at 140, the greater proportion of which consists of copper mines. The veins or lodes vary in thickness from three inches to thirty feet. The excavations are sometimes wrought to a very great depth. In the consolidated mines there is a shaft, in the parish of Gwenap, between Truro and Redruth, which is 265 fathoms deep. Two large steam-engines are not unfrequently employed upon one mine; and there are instances where the sinking of the shaft, and a single engine with its apparatus, have cost upwards of L.10,000. The power of steam-engines at present employed in the Cornish mines is probably equivalent to that of from 45,000 to 50,000 horses. The mines in Cornwall are generally undertaken by companies of adventurers. If the mine be upon a waste it is the property of the king, as Duke of Cornwall, to whose agents the adventurers apply for a lease; if it be private property its owners are of course applied to, and it is usually let for twenty-one years, or for such portion of that

¹ Pryce, *Mineralog. Cornub.*, Introd. p. 8.

Mines.

time as the workings shall be proceeded in. The rent varies, according to circumstances, from one eighth to one thirteenth of the ores raised. The miners are sometimes paid by the piece, and sometimes by a certain per centage upon the ores raised by them. They relieve each other by turns, each set generally continuing in the mine for eight hours; but when working at the bottom of deep shafts they relieve each other every six hours.

Tin and copper mining, like that of the precious metals, is exceedingly precarious. There is no certainty beyond the actual moment. Veins which promise much when first opened sometimes fall off below and occasion immense loss to the adventurers, or continue to be wrought in hopes of improvement, but with little or no profit; whilst, on the other hand, mines and veins which, at the outset, promised little or nothing, come in time to yield very large profits. Hence, if great losses often occur, enormous fortunes are sometimes realised. Crennis copper mine returned a clear profit to the adventurers of L.84,000 in one year; and Huel yielded nearly L.130,000, after defraying every necessary outlay. The expense of working some of the large mines is very great. In that of Huel Vor, 3000 lbs. of candles and 3500 lbs. of gunpowder are consumed in a month. The total amount of capital employed in connection with the tin and copper mines of Cornwall has been estimated at L.2,440,000; and the total number of persons to whom they afford occupation directly or indirectly is supposed to be 76,000. The miners and others engaged in the tin mines of Cornwall and Devonshire are under the especial protection of the Stannary Courts, which were established about five hundred years ago, and have not undergone any material alteration since the reign of Charles II. These courts are held by the lord warden of the stannaries; and no miner or other person really engaged in the mines can be sued in any other court except upon pleas of land, life, or member. From the Stannary Courts no writ of error lies to any court in Westminster Hall; but an appeal may be taken to the privy council of the Duke of Cornwall.¹

5. Lead Mines.

With the exception of iron, lead is perhaps the most abundant of the metallic substances found in Europe. The most common ore of this metal is the sulphuret or galena, which occurs massive, or crystallized in various forms, and is met with not only in primitive, but also in secondary mountains, being generally deposited in veins or extensive beds. The rocks in which it is most commonly distributed are gneiss, mica, schistus, limestone, and greywacke; and the mineral substances which constitute the matrix or *gangue* are quartz, barytes, lime spar, and fluor spar. The ores of lead are likewise accompanied by a great number of other metallic substances, particularly by some of the ores of zinc, as blende and calamine, iron and copper pyrites, sparry iron ore, and red vitreous silver ore.

The lead mines of Great Britain are numerous and important. That the mines of Derbyshire were wrought in the time of the Romans, is evident from the blocks of lead which have been found with Roman inscriptions on them.² But, excepting in these, it does not appear that lead was obtained anywhere in England until the year 1289, when it was discovered in Wales; and the fact having transpired that silver was found intermixed with the Welsh ores, this gave

a fresh stimulus to the business. In other respects, however, the discovery of silver was of no avail, as the quantity obtained proved altogether insufficient to defray the expense of separating it from the lead. At present the most productive lead mines are situated in Allendale and other parts of Northumberland; in Aldstone Moor and its vicinity in Cumberland; in the western parts of Durham; in the hundred of High Peak in Derbyshire; in some parts of Flintshire; at Leadhills and Wanlockhead, and on the confines of Dumfriesshire and Lanarkshire, in Scotland.

It is not easy, for want of returns, to arrive at a correct estimate of the annual produce of these mines; but in the aggregate it must be very considerable, amounting probably to between 45,000 and 50,000 tons. The foreign lead imported is almost all re-exported; and hence the supply obtained from our own mines must not only be sufficient to satisfy the home consumption, which is very great, but, as our exports exceed our imports by from 10,000 to 14,000 tons, to furnish this quantity in addition. Lead has declined in price since the year 1820, owing to the increased supplies obtained from Spain, and the comparatively cheap rate at which these are furnished. This metal is raised in different parts of Ireland, as in the county of Wicklow, at Carne in Wexford, and in Armagh and Donegal; but some of the lead mines which were formerly wrought in Kerry and Mayo have been abandoned.

The mineral called *black lead* or *plumbago* is found at Borrowdale in Cumberland, where mines of it have been wrought since the days of Queen Elizabeth, and furnish the best material hitherto discovered for making pencils. Formerly the proprietors of these mines enjoyed a complete monopoly of the market; and by occasionally shutting them up, and thus diminishing the supply of the mineral, they kept its price at a high level, and realised large profits. But, latterly, plumbago has been imported in considerable quantities from Mexico and Ceylon; and, although inferior in quality, yet, being cheaper than the English, it has superseded the latter for most purposes, except the best kind of pencils. The lead is not found in veins, but in detached pieces; it is often lost, and the miners are frequently engaged for a long time in seeking at random for a new supply. The quality of the mineral differs materially, the lightest being the best. It is cut into the proper form for pencils by the manufacturers of Keswick and London.

6. Salt Mines.

No country is better supplied than England with beds of fossil or rock salt, and also with brine springs. The latter, which occur at Northwich, Winsford, Middlewich, and other places adjacent to the Weaver in Cheshire, and at Droitwich in Worcestershire, have been known and wrought from a remote era. But it was not until a comparatively recent period that the beds of fossil salt were discovered, the first of them having been met with in 1670, about thirty-four yards below the surface, in searching for coal in the vicinity of Northwich. In 1779 a second bed of fossil salt was discovered near Lawton, about forty-two yards below the surface; and others have since been found in different parts of the surrounding country. These beds, or strata, are generally of very great thickness; and, upon cutting through the indurated marl at the bot-

¹ Phillips' Mineralogy, p. 194, et seq. Guide to Mountshay, p. 190, second ed. Blackstone's Commentaries, book iii. c. 6.

² A block of lead of this kind was discovered on Cromford Moor in the year 1777, with the following inscription:—"The sixth legion inscribes this in memory of the Emperor Hadrian." Another block was found at Matlock Bank in 1783, inscribed thus:—"The property of Lucius Aruconius Verecundus, merchant of London." The weight of this block was 84lbs. A third block, weighing 1½ cwt., was subsequently discovered at Matlock, and upon it was found this inscription:—*TI. CL. TR. LUT. BR. EXARG.*, probably meaning *Tiberii Claudiani Triumviri Lutudari Britannorum Exargentaria*. The Saxons and Danes, it is also supposed, were engaged in working the lead mines of Derbyshire.

Mines.

Mines. tom of the first stratum, another of still greater thickness has sometimes been discovered below it. In one instance a third bed has been pierced, of twenty-five yards, without reaching the lower surface of the stratum. There are also beds of fossil salt at Droitwich; but as these have not been wrought, comparatively little is known respecting them.

Rock salt, when dug from the mine, is seldom of such purity as to admit of its being used without undergoing some process of refining. The largest portion of the salt produced in Cheshire, and nearly the whole of that produced in Worcestershire, are obtained from the brine springs. In Cheshire, the brine being pumped up from deep wells, is collected in reservoirs, and, being saturated by means of crushed rock salt, is thence conveyed into large, broad, shallow pans, placed over furnaces, where the water which holds the salt in solution is evaporated, and the salt rendered fit for use. Different qualities of salt are produced, according to the mode in which the heat is applied, and the process of evaporation conducted. Animal jelly, butter, and other foreign substances, are sometimes employed to assist in clearing the brine, and in granulating the salt. Salt has been obtained from the brine pits at Droitwich for at least a thousand years. When these are dug to a sufficient depth, the brine ascends to the surface. But the quantity of white salt made here is very inferior to that produced in Cheshire, and this place does not furnish any supplies of fossil salt. Part of the rock salt of Cheshire is refined at Newcastle and other places.

The consumption of salt in this country is immense. In those provinces of France which had purchased an exemption from the *gabelle*, Necker estimated the consumption at 19½ lbs. for each individual; but, from the difference of our food and habits, the consumption of the people of this country may be estimated a little higher, or at 22 lbs. each person. On this supposition, and taking the population at 16,500,000, the entire consumption of Great Britain, exclusively of Ireland, will amount to 363,000,000 lbs., or 161,000 tons. But, besides this, between 11,000,000 and 12,000,000 bushels, equivalent to about 300,000 tons, are exported to the United States and the British North American colonies, to Holland and Belgium, Russia, Denmark, and other countries. In ancient Rome salt was subject to a duty (*vectigal salinarum*); and it has generally been heavily taxed in modern times. The *gabelle*, or code of salt laws, formerly established in France, was most oppressive, and its severity had no inconsiderable share in bringing about the Revolution. In this country the duties upon salt, which were first imposed in the reign of William III., amounted, in 1798, to 5s. a bushel, and were subsequently increased to 15s. a bushel, or about forty times the cost of the article taxed. So exorbitant a duty was productive of the worst effects, occasioning a great deal of smuggling; and, the opinion of the public having been strongly expressed against it, the tax was finally repealed in 1823.

7. Mines of Manganese and Zinc.

Manganese, a mineral substance of considerable consequence in the arts, exists chiefly in the state of oxide, and sometimes in that of carbonate. The ores appear under a great variety of forms, and it has hitherto been found extremely difficult to reduce them to the metallic state; but it is easy to detect a large quantity by means of the blow-pipe, the action of which, with the addition of borax, and a little nitre, produces a violet-coloured glass. This mineral is found at Upton-Pyne in Devonshire, and in the

Mendip Hills, Somersetshire, from which it is obtained in quantities sufficient to meet the demand. In Scotland, the ores of manganese have not been discovered in such abundance as to become an object of pursuit.

Zinc has never been met with in the metallic state. It exists in the form of sulphuret, in that of oxide, and also in the state of carbonate. The ores of zinc are very common in several of the lead mines of Great Britain, where the metal is found sometimes in the form of blende, or sulphuret, and sometimes in that of calamine, or oxide. It is obtained from the mines of Derbyshire, particularly at Castleton, Cromford, Bonsal, and Wirksworth; but Flintshire and the Isle of Man furnish ores of the best quality. At Leadhills, in Scotland, blende, and some of the varieties of calamine, are frequently met with. The blende is occasionally found in great abundance; sometimes it occurs in detached masses, and sometimes it occupies the whole vein, to the exclusion of the lead ore.

8. Stone and Slate Quarries.

The stone quarries of England are not of any great value or importance. The principal are situated in the Isle of Portland, and in the neighbourhood of Bath. The annual produce of the Portland quarries may be estimated at about 18,000 tons. From them have been obtained the stones employed in the construction of St Paul's, and in that of most other public buildings in London. The quarries of Gateshead Fell, near Newcastle, furnish the grindstones universally known by the name of *Newcastle grindstones*. Scotland is distinguished for the number and excellence of its quarries. But those of Craigleith, Cullaloe, Fifeshire, and some others, are amongst the most celebrated. The general beauty of the houses in the New Town of Edinburgh attests the excellency of the stone of which they are built, and which has been principally furnished by the Craigleith quarry. Large quantities of granite are shipped from Aberdeen for London, where it is employed in various public works, and likewise in paving the streets. The Liverpool docks have been partly constructed of granite brought from Kirkcudbrightshire.

The principal slate quarries in Great Britain are situated in Caernarvonshire. Those belonging to Mr Pennant are the most extensive and valuable, furnishing employment for about 1500 men and boys. The other slate quarries in Caernarvonshire and North Wales employ generally about 1800 men and boys. There are also extensive quarries in different parts of South Wales, at Ulverstone in Lancashire, and in other places. The principal slate quarries of Scotland are in the island of Easdale, and at Ballachulish in Argyshire; but, speaking generally, they do not furnish slates of the same size and smoothness as those obtained from the Welsh quarries.¹ The slate quarries near Dunkeld are worked under great disadvantage, owing to their distance from any port of shipment; and hence the supply is almost wholly limited to the demand of the country immediately adjacent.

III.—CONTINENTAL MINES.

Most of the mineral and metallic substances which abound in Great Britain and Ireland have also been discovered, and to a certain extent excavated, in one or other of the countries of the continent of Europe; and the latter likewise afford a variety of mineral products which, as compared with those of Great Britain, are peculiar to them-

¹ See M'Culloch's Statistical Account of the British Empire, vol. ii. chap. 2. To this great repository of valuable information we have to acknowledge pre-eminent obligations on the subject of British mines and minerals, which are treated of at length in the chapter above referred to.

Mines. selves. In addition to coal, iron, tin, copper, lead, zinc, manganese, &c. they furnish, in greater or less quantities, gold, silver, mercury, and various other metals or mineral substances, some of which are equally valuable and useful. We shall therefore endeavour to give a short account, first, of those minerals and metals which they possess in common with this country; and, secondly, of those which are comparatively peculiar to themselves, or, in other words, what are not found at all, or only to a very trifling extent, in Great Britain and Ireland.

1. Coal Mines.

Before the war of the Revolution, England supplied the maritime parts of France with coal. But the declaration of hostilities having put an end to this trade, and thus deprived these parts of their ordinary supply, the rulers of France directed their attention to the improvement of her internal resources; and, amongst other objects of research, the discovery of coal was too important to be neglected. Wherever any favourable indications presented themselves, the attempt was accordingly made, and it appears in many cases to have been prosecuted with considerable success. Indeed an inspection of the map of France, on which the coal districts are delineated, would lead us to suppose that one half of that country contains coal; but there are many circumstances which tend to show that the extent of the coal strata is much more limited, and that the representations which have been made on the subject, in certain official documents, are greatly exaggerated. In a report addressed to the consular government, it is stated that coal is wrought in forty-seven departments, and that sixteen others afford indications of the same mineral. But of the forty-seven departments in which coal mines are stated to be wrought, reports of the products of thirty-four only were obtained; and, from the estimated annual amount of coal produced in these departments, it appears evident that the total annual produce of the coal mines of France, at the period referred to in the report, could not have exceeded 5,000,000 tons. That a considerably larger supply has since been obtained, cannot admit of any reasonable doubt; but, whether from the comparative barrenness of the mines, the difficulty of working them, or inferiority of skill and less perfect machinery, to say nothing of the relative quality of the coal produced, it appears that, even at the present day, English coal might be exported to France and sold at a price considerably lower than French. The coal which has been found in the southern parts of France is very generally of an inferior quality, the best mines being those which are situated in the department of Aveyron, on the banks of the Lot and the Dordogne. In the central parts it is met with in greater abundance, though not always of a good quality; and the coal on the eastern frontier seems to be of no great importance. In the western parts, the mines of Montrelais have long furnished a considerable supply to the country situated upon the banks of the Loire. But the richest coal mines in the kingdom occur in that part of France which lies between Calais and the Rhine; indeed the produce of the coal mines of the North amounts to nearly three fourths of that of the whole kingdom. The most important coal fields in this part of the country are those of Boulogne, Jemappes, and Anzin.

No coal has yet been discovered in any part of Spain or Italy, nor have any indications of the existence of that mineral presented themselves in either of these countries. But in several parts of Germany, and in Bohemia, there

are valuable mines, some of which yield coal in considerable abundance. The northern countries of Europe are, for the most part, entirely destitute of this species of fossil fuel. Coal is indeed found in several parts of the Russian empire, but it is of so bad a quality as to be almost unfit for use. Some appearances of this mineral were observed by Olivier on the shores of the Black Sea; pit-coal has also been met with in the vicinity of the Donetz; and to the north of Taganrog there is an immense stratum, twenty-four feet in thickness, consisting of slate coal of very inferior quality.

2. Iron Mines.

The iron manufacture of France has been very greatly extended since the commencement of the Revolution, and is protected by high duties, which secure to the native manufacturer the almost exclusive possession of the French market. The iron ores are chiefly met with in the vicinity of the Pyrenees, being deposited in veins, some of which are from six to eight feet in thickness; and iron stones are also abundant in France, particularly in those departments where coal strata prevail. Latterly, great exertions have been made by the French government to encourage and extend the native manufacture of iron;¹ but the metal produced is still vastly inferior in quality to the English and Scotch, and is at the same time considerably higher in price. The principal iron mines of Spain are situated in the provinces of Biscay and Catalonia; and the ores from which the metal is extracted consist of the sparry kind, together with red and brown hæmatites. Many parts of Germany have long been celebrated for the abundance and excellence of the iron extracted from the native ores, particularly in Styria, Carinthia, and Franconia.

The island of Elba possesses one of the richest iron mines in the world, the existence of which appears to have been known from the earliest times. The ore is chiefly of the specular kind, and the mass constitutes an entire mountain, which is surrounded by others consisting of granite, of which the island is almost wholly composed. This mountain, which is called Rio, is about 500 feet in height, and three miles in circumference; and its surface is covered with a reddish ochry earth, which in some places is several feet in thickness, and full of small shining scales of iron ore. Beneath this covering, the mass of the mountain consists of metallic ore, or rather, it is composed of accumulated masses, thrown together without any order or stratification. These masses are deposited in an ochry substance, which may be considered as their matrix; and, besides the specular ore, which predominates, other species and varieties are occasionally met with. The iron mines of Elba were wrought in the time of the Romans, by means of excavations carried into the mountain; but now the ore is extracted by the ordinary process of quarrying. It has been conjectured by some that the mass of iron ore in the island of Elba is part of a great vein of immense extent running into the adjacent continent.

The iron mines of Sweden have long been celebrated on account of the rich ores which they afford, and the superior quality of the iron which is thence obtained. The most remarkable are those of Danemora, distant four Swedish miles from Upsal, and which were first discovered in 1470. The mines are in primitive rocks, and the ore is said by some to be found in enormous masses, though, according to others, it is deposited in the form of a great vein. It is wrought to the day, and the greatest depth is less than

¹ This is evinced in the able Report made to the director-general of mines in France, by M. Dufrenoy, on the use of hot air in the iron-works of England and Scotland (Paris, 1834, and London, 1836). It is not a little singular, that we should be indebted to a foreigner for the first detailed account of the progress of an invention which had its birth in Scotland, and which has in that country been attended with signal success.

Mines. a hundred fathoms. From 1200 to 1500 persons are constantly employed in the different operations connected with these mines. The mountain of Taberg in Smaland is almost entirely composed of iron ore; it consists of a great number of veins running in a vertical position, parallel to each other; and the ore is a mixture of the specular kind with clay and small grains of felspar, thus exhibiting the appearance of porphyritic rock. The mines of Arendal in Norway furnish abundance of iron ore mixed with garnets and other minerals which are found only in primitive rocks. The Ural Mountains, so rich in other metallic ores, contain also mines of iron, from which is derived the greater part of that metal employed in Russia. In one part of Siberia, iron is extracted from an ore consisting of ferruginous fossil wood imbedded in clay and sand.

3. Tin Mines.

That portion of the west of France which is, as it were, projected between Cornwall in England and Galicia in Spain, has been supposed to afford indications of tin, probably from some similarity in geological structure; but, in point of fact, none has yet been discovered. Ores of this metal have, however, been found in Galicia, and on the frontiers of Portugal, where, in the year 1787, a mine was opened, and veins, some of them six feet in thickness, began to be wrought. These veins were included in granite. Tin mines were formerly wrought in the north of Portugal, and traces of the ore are still visible. At Marienberg in Germany a mine is wrought, in a vein about six feet thick, which runs from east to west, like those of Cornwall, with an inclination of about 70°. The mountain in which the tin mines of Ehrenfriedersdorf are situated, contains, within a space of about a hundred fathoms, a great number of parallel veins, running in the same direction, and some of them almost in contact with one another; so that, in the thickness of about three fathoms, there are sometimes found four or five veins, the hanging side of one vein forming the ledger side of the other. These veins traverse a rock of argillaceous schistus, but none of them has been wrought to any great depth. There are also tin mines at Altenberg, Geyer, and Zinnwald, which, with that just mentioned, produce annually about 4000 cwt. of metal. The tin mines of Platte in Bohemia are, as usual, in granite, and the veins traverse the rock in a direction approaching to that of east and west. In the Kaff Mountain there is a tin mine in which iron ore is found at the top of the vein, and tin at a greater depth; and it has been conjectured that, were the mining operations carried to a still lower depth, silver ores would be found. But the most remarkable tin mine of Bohemia is that of Schlackenwald, where the ore is deposited in the form of accumulated masses or stockwerks. One of these masses, shaped like an inverted cone, is of very considerable magnitude, being from ninety to a hundred fathoms in thickness. It is surrounded by gneiss, and the mass itself is composed of granite, in which are disseminated grains of tin ore. This mine has been wrought for more than five centuries, and has been carried to a depth of about a hundred fathoms; but the ore is so disseminated in the rock, that it requires ten thousand quintals to yield from thirty-five to forty quintals of tin.¹

4. Copper Mines.

The copper mines of France do not appear to be of any great importance. Those of Bigorre, in the western Py-

renees, are now nearly exhausted, and the mines of Lan-guedoc are not productive; the most valuable are those of Chessy and St Bel near Lyons, the annual produce of which is between 3000 and 4000 quintals of copper. The ore found at the latter place consists chiefly of copper pyrites, which yields only about three per cent. The copper mines of Spain are situated on the frontiers of Portugal, but appear to be of as little consequence as those of France. The ore is copper pyrites, affording from four to six per cent. of metal. There is a tradition that one of these mines was wrought in the time of the Carthaginians. Germany contains some valuable copper mines, amongst which may be mentioned those of Hesse, where the ore is deposited in a bituminous stratum of marl schistus, from four to eight inches in thickness, but of great extent. The ore contained in this stratum or bed consists chiefly of copper pyrites; but vitreous copper ore, and red oxide of copper, are sometimes met with. Of the Hessian mines, the most considerable is that of Riegelsdorf, which yields annually about 2500 quintals of copper. There are similar mines at Frankenberg near Cassel, at Bieber in Hanau, at Eisleben in the county of Mansfeld, and also in the district of Magdeburg. In Hungary there are some valuable copper mines, particularly those of Herengrund near Neusohl, where the mineral is found in the form of gray copper ore, deposited in beds of considerable thickness, amongst a breccia of micaceous schistus.

But one of the most extensive and most productive copper mines in the world is that of Fahlun, in the province of Dalecarlia, in Sweden. The mining district occupies a space of nine leagues in length by two and a half in breadth, and is surrounded by a reddish granite, which becomes of a finer grain as it approaches the centre of this space, and is then succeeded by a micaceous rock dividing into rhomboidal fragments. The principal mass, which is of enormous dimensions, consists of iron and copper pyrites lying in a vertical position from north-west to south-east along the valley in which it is deposited. Here there is an immense opening or gulf 840 feet in length, 720 in breadth, and 240 in depth, which was produced in the year 1687, by the falling in of the superincumbent mass, in consequence of the unskilful manner in which the subterranean operations had been conducted. In this celebrated mine the mass of ore is described as lying in the form of an inverted cone, and the excavation has been carried to a depth of more than 200 fathoms; but it is supposed that this is nearly the utmost extent to which the mass of ore penetrates the earth, as latterly the operations have been conducted upon a more limited scale than in former times. It was in this mine that Gustavus Vasa, when driven from his throne, worked for a time, to procure the means of subsistence. In the mine of Garpenberg, which is about eighteen leagues from that of Fahlun, there are fourteen veins in a vertical position, and all parallel to one another, being situated in a quartzose micaceous schistus, which is also disposed parallel to the veins.

In Siberia there are two principal mines of copper, which are both situated in the extensive chain of the Ural Mountains. One of these, that of Goumechefschi, about fourteen leagues to the south-west of Katherineberg, is in the central part of the chain, in a kind of plain, upon the border of a lake, surrounded by primitive mountains. The vein is nearly in a vertical position, being disposed between a bed of primitive white marble and an argillaceous schistus in a state of incipient decomposition. The matrix of the ores is a clay of different colours, and they consist

¹ The tin of the East Indies, particularly that of the island of Banca, is considered as purer than the tin of Europe. Great quantities of the former are now imported. The mines of Banca have already yielded more than 4,000,000 lbs. of metal, and the veins are still far from being exhausted.

Mines. chiefly of native copper in grains and small masses, with some vitreous copper ore; whilst the fissures and cavities are encrusted with malachite, some beautiful specimens of which have been obtained. The length of the vein is about 200 fathoms, and its thickness varies from one to ten fathoms. The ore yields only between three and four per cent. and the amount of copper annually produced is about 4000 quintals. The other Siberian mines are those of Tourinski, on the river Touria, at the eastern base of the Ural chain, and about a hundred leagues north of Katherineberg. The vein is included in a bed of white marble, which in thickness does not exceed four fathoms. The matrix of the ores is clay, but it is rich, and often exhibits a beautiful appearance, being varied with veins of blue and green steatites, red oxide of copper, fragments of malachite, gray ore, and not unfrequently native copper. The ore yields from eighteen to twenty per cent., and the annual produce is about 20,000 quintals.

5. Lead Mines.

France possesses considerable mines of lead, particularly those of Poullaouen and Huelgoet, in the department of Finisterre, which have been worked into two parallel veins included in primitive rocks. There are also mines of lead in the Vosges, where the galena is disseminated in a thick vein of decomposed granite; in the department of Sambre and Meuse, where the veins traverse limestone nearly in a vertical position; and in other places, where, in their distributions and productions, the mines are analogous to those of Great Britain. The produce of the French mines is about 30,000 quintals of lead annually. There are many valuable mines of lead in Germany, particularly in Saxony and the Hartz. Lead ore is also obtained from the mines of Hungary and Bohemia, which sometimes yield a considerable proportion of silver. The mines of Bleyberg, in Carinthia, where galena is the prevailing ore, furnish the finest specimens of molybdate of lead. At Tarnowitz in Silesia there is a remarkable deposition of lead ore, the beds in which it is distributed reposing on horizontal strata of compact limestone, which contains petrified shells, and is impregnated with bituminous matter. The lead ore is deposited in veins, in rounded masses, and in small grains. The only appearance of lead in the immense chain of the Ural Mountains, so rich in other mineral productions, is in the state of chromate, or red lead, which was first discovered in Siberia, and the principal repository of which is the gold mine of Beresof. It is found in a small vein of ferruginous quartz, traversing a gneiss rock of a reddish colour.

6. Mines of Zinc and Manganese.

In a lead mine about six leagues from Cherbourg in France there is a vein of calamine four fathoms in thickness; and in the neighbourhood of Aix-la-Chapelle there is a prodigious mass of calamine imbedded between two rocks, composed of micaceous schistus and sandstone, intermixed with very hard quartz. The ore is extracted by sinking shafts, from the lower extremities of which galleries have been driven, some of them to a very considerable extent. When the ore is exhausted on this level, the shafts are sunk deeper, and a new series of operations is commenced. An immense mass of blende, or sulphuret of zinc, was discovered by Dietrich in the Pyrenees; and ores of this metal are not uncommon in other parts of France. A pure calamine, containing neither iron, lead, nor sulphur, was found near Alcaraz in La Mancha, Spain, and was extracted for the purpose of being employed in the manufacture of brass carried on in the vicinity of that place; but the work appears to have been latterly discontinued.

Mines. Some ores of zinc abound in the mines of Saxony, and in those of the Hartz, where they are found in considerable quantities, and also in peculiar repositories. A mass of blende, similar to that observed in the Pyrenees, was discovered in the Hartz, unmixed with any other metal, and capable of affording any quantity of ore.

France possesses some valuable mines of manganese, particularly that of Romanèche, in the department of Saone and Loire, which is situated on the eastern declivity of a chain of primitive mountains, stretching from north-northeast, and composed of granite, limestone, and a siliceous sandstone. The manganese is incumbent on the granite, forming neither a bed nor a vein, but being deposited in a kind of accumulated mass, about ten fathoms in its greatest breadth, and nearly two hundred in length. The thickness of this mass of manganese varies from seven to fifteen feet, and the greater part of it is free from admixture with other minerals, except fluor spar of a deep violet colour, with which it is sometimes found combined. Manganese is also found in other parts of France, as in the Cevennes, where it occurs in a matrix of granite; in the department of the Vosges and the Moselles; and in the neighbourhood of Perigueux, in the department of Dordogne. The manganese mine in the valley of Aoste, Piedmont, has been described by Saussure in his *Voyages*. It is situated in a mountain of gneiss, the beds of which are nearly horizontal; and the ore is supposed to be deposited in the form of a large mass rather than in that of a bed or vein. This mine affords fine specimens of the carbonate of manganese, crystallized in the form of rhomboidal prisms, and of a beautiful purple-red colour. Ores of this metal are not uncommon in various parts of Germany. The carbonate has been found in the gold mine of Nagyag, and in other auriferous mines of Transylvania. In the Ural Mountains there is a siliceous sandstone, which is entirely penetrated with manganese, disposed in a dendritical form, throughout the whole mass of the stone.

7. Mines of Rock Salt.

Fossil salt is usually found alternating with beds of clay, accompanying gypsum, sandstone, and limestone; sometimes in considerable beds, but often in detached masses, and also in veins. Mines of rock salt occur in Hungary, the southern part of Germany, at Vic in France, and also at Wielizka in Poland. The last of these are of prodigious extent, and afford annually about 2,000,000 cwt. of this fossil product, without any appearance of exhaustion.

Having thus noticed the various mineral products which the continent of Europe possesses in common with Great Britain, and also indicated their respective localities in the different countries, we now proceed, in conformity with our plan, to give some account of those which may be considered either as peculiar to the Continent, compared with Great Britain, or which occur there in sufficient abundance to be extracted from their ores, and for this reason come within the scope of the present article.

1. Mines of Gold and Platina.

Gold, though one of the scarcest metals, is almost universally distributed. It is most frequently found disseminated, or in detached grains, or in a dendritical form, and sometimes it occurs in a crystallized state. It is often met with in primitive mountains, where it is usually distributed in veins, and occasionally disseminated in the rock itself. The gangue or matrix of gold, that is, the substances which accompany it, consist of quartz, felspar, limestone, pyrites, some of the ores of silver, and galena; and it is also found in combination with manganese, cobalt,

Mines. and nickel. In a Siberian mine, gold has been discovered surrounded by muriate of silver. It is likewise common to alluvial soil, where it is disseminated in grains, along with siliceous, argillaceous, and ferruginous sands, which form the component parts of certain soils. It is further met with in the sands of many rivers, particularly after floods. Most of the auriferous sands are of a black or reddish colour, and consequently are ferruginous; a circumstance which, taken in connection with the gold of alluvial soil, has led some to suppose that its presence is owing to the decomposition of auriferous pyrites.

Platina exists in the metallic state, and is usually found in the form of small, flat, or rounded grains. Its colour is a light steel gray, or silver white; it is ductile, and in thin plates flexible; but it is infusible without addition. Platina was first known in Europe about the year 1748, and, until Vauquelin detected this metal in a gray silver ore from the mine of Guadalcanal in Spain, it was found only in South America, where it occurred in alluvial soil covered with rounded masses of basalt. It is now found in considerable quantities on the European side of the Ural chain. Platina is accompanied with particles of gold and iron, and with another ore containing osmium and iridium; and it forms the alloy of rhodium and palladium.

The principal mines of gold and platina in Europe are those belonging to Russia; but before proceeding to give some account of these, we shall shortly advert to the different localities where gold has been found and wrought in some of the other countries of the Continent.

In several parts of France gold has been found, although in exceedingly small quantities. In the year 1781, a vein of gold was discovered at Gardette, in the valley of Oysans, which is situated in the department of the Isère. This vein consisted of quartz, which traversed a gneiss mountain, and contained auriferous sulphuret of iron, besides some fine specimens of native gold; but the quantity obtained was found insufficient to defray the expense of operations. Many of the rivers, as the Rhone, the Rhine, the Garonne, and others of smaller note, furnish auriferous sand. Veins of auriferous sulphuret of iron traversing gneiss rocks have been discovered at the foot of Mount Rosa in Piedmont; and the sands of some of the rivers, as well as various parts of the soil, on the south side of the Apennine Mountains, are likewise auriferous.

It has been said that the mineral wealth of Spain and Portugal is now almost exhausted; but it would perhaps be nearer the truth to state, what is undoubtedly the fact, that, in these countries, the search for mineral treasures has long been in a great measure abandoned. From the earliest times the Peninsula has been celebrated as a repository of gold, which was found, not only in the alluvial soil and in the beds of rivers, but also in regular veins, and which might still be discovered in considerable quantities, were it not afforded in much greater abundance by various parts of Africa and South America. This precious metal was collected in the Peninsula by the Phœnicians, and afterwards by the Romans, who, according to the statements of the ancient writers, obtained annually from Portugal, and from Galicia and the Asturias, 30,000 marcs, or 240,000 ounces, of gold.

Amongst the places of Europe which are most remarkable for mines of gold, and also for auriferous sands, may be mentioned Schemnitz and Kremnitz in Hungary. The gold of Schemnitz is accompanied by silver, lead, and iron pyrites, the native matrix being quartz. The mines of Nagybanja, Kapnik, Felscebanja, Wiszbanya, and Olaposbanja, all yield gold; whilst those of Nagyag, Korosbanja, Vœrœspatah, Boitza, Csertes, Fatzbay, Almas, Porkura, Botschum, and Stonischa, furnish chiefly gold and copper. The gold mine of Nagyag furnishes gold in combination with native tellurium. The whole produce of the Hun-

Mines. garian mines amounts to 5200 marcs or 3250 lbs. troy of gold. At Edelfors in Sweden native gold and auriferous iron pyrites are deposited in a vein of brown quartz traversing a mountain of schistose hornstone. Gold is also met with disseminated in the rock itself.

We come now to the gold and platina district of Russia, of which Humboldt has given a description in a letter to his friend Arago. "We spent a month," says he, "in visiting the gold mines of Borisoosk, the malachite mines of Goumeselvoki and of Tagilsk, and the washings of gold and platinum. We were astonished at the *pepitas* (water-worn masses) of gold, from two to three pounds, and even from eighteen to twenty pounds, found a few inches below the turf, where they had lain unknown for ages. The position and probable origin of these alluvia, mixed generally with fragments of greenstone, chlorite slate, and serpentine, was one of the principal objects of this journey. The gold annually procured from the washings amounts to 6000 kilogrammes. The discoveries made between 59 and 60 degrees of N. latitude, are important. We possess the teeth of fossil elephants enveloped in these alluvia of auriferous sand. Their formation, consequent on local irruptions and levellings, is perhaps even posterior to the destruction of the large animals. The amber and the lignites, which we discovered on the eastern side of the Ural, are decidedly more ancient. With the auriferous sand are found grains of cinnabar, native copper, ceylamites, garnets, little white zircons as brilliant as diamonds, anatase, alvite, and other stones. It is very remarkable, that in the middle and northern parts of the Ural, the platinum is found in abundance only on the western European side. The rich gold washings of the Denidor family at Nijneï-Tagilsk are on the Asiatic side, on the two acclivities of the Bartiraya, where the alluvium of Vilkni alone has already produced more than 2800 lbs. of gold.

"The platinum is found about a league to the east of the line of the separation of waters (which must not be confounded with the axis of the high summits) on the European side, near the course of the Oulka, at Sukoi Visnia; and at Martian, M. Schevetsov discovered chromate of iron, containing grains of platinum, which an able chemist at Katherineberg, M. Helm, has analysed. The washings of platinum are so rich that a hundred poods (about 400 lbs. Russian) of sand afford thirty, and some fifty, solotnicks; whilst the rich alluvia of gold at Vilkni, and other gold washings on the Asiatic side, do not give more than one and a half to two solotnicks of platinum to a hundred poods of sand. In South America, a very low chain of the Cordilleras, that of Cali, also separates the auriferous and non-platiniferous sands of the eastern declivity (Popayan) from the sands of the isthmus of the Raspadura of Choco, which are very rich in platinum, as well as gold. We possess pepitas of platinum many inches in length, in which M. Rose has discovered beautiful groups of crystal of that metal.

"As to the greenstone porphyry of Laya, in which M. Engelhardt observed little grains of platinum, we have examined it on the spot with much care; but the only metallic grains which we have been able to detect in the rocks of Laya, and in the greenstone of Mount Belayr-Gora, have appeared to M. Rose to be sulphuret of iron; this phenomenon, however, will be a subject for new research. Osmium and iridium have also a peculiar locality, not amongst the rich platiniferous alluvia of Nijneï-Tagilsk, but near Belemboyevski and Kichtem. I insist upon the geognostical characters drawn from the metals which accompany the grains of platinum at Choco, Brazil, and in the Ural."

The following table exhibits the produce of the gold and platina mines of Russia from January 1826 to July 1830.

Mines.

GOLD.

PLATINA.

Produce of Gold and Platina for the first Six Months of 1832. Mines.

<i>January to July 1826.</i>			
	pds.	liv.	zol.
Crown mines.....	37	14	36
Private mines.....	82	33	80
	120	8	20

<i>July to December 1826.</i>			
	pds.	liv.	zol.
Crown.....	32	27	91
Private.....	78	29	20
	111	17	15

<i>January to July 1827.</i>			
	pds.	liv.	zol.
Crown.....	48	3	34
Private.....	92	24	73
	140	28	11

<i>July to December 1827.</i>			
	pds.	liv.	zol.
Crown.....	41	26	18
Private.....	99	25	72
	141	11	90

<i>January to July 1828.</i>			
	pds.	liv.	zol.
Crown.....	45	16	80
Private.....	111	10	67
	155	27	51

<i>July to December 1828.</i>			
	pds.	liv.	zol.
Crown.....	42	10	53
Private.....	92	5	47
	134	16	4

<i>January to July 1829.</i>			
	pds.	liv.	zol.
Crown.....	46	8	0 $\frac{1}{4}$
Private.....	95	34	46 $\frac{1}{4}$
	142	2	46 $\frac{1}{2}$

<i>July to December 1829.</i>			
	pds.	liv.	zol.
Crown.....	54	1	86
Private.....	91	26	53
	145	28	43

<i>January to July 1830.</i>			
	pds.	liv.	zol.
Crown.....	81	36	75
Private.....	98	2	95
	179	39	75

In addition to this, we are enabled to give, from a parliamentary paper,¹ a statement of the produce of the Russian gold and platina mines during the year 1832; which statement was furnished to Viscount Palmerston by Mr T. J. Gisborne, his majesty's consul at St Petersburg. This return is dated St Petersburg, 5th April 1833, and is as follows:—

Gold.	poods.	lbs.
Crown works.....	90	13
Private ditto:		
A. Yacovleff's.....	32	24 $\frac{1}{3}$
Rastorgouyeff's.....	21	30 $\frac{1}{3}$
Demeedoff's.....	16	4
J. Yacovleff's.....	13	17 $\frac{1}{3}$
Tourchaneenoff's.....	7	14 $\frac{1}{3}$
Yartzoff's.....	3	33
Goubin's.....	1	30 $\frac{2}{3}$
Countess Strogonoff's.....	1	21
Vsevoloshky's.....	4	0
Countess Polier's.....	1	24
Major's.....	1	18 $\frac{1}{2}$
Gousetnikoff's.....	0	2
Total.....	195	32 $\frac{1}{2}$

Platina.	poods.	lbs.
Crown works.....	0	4 $\frac{1}{3}$
Private ditto:		
Demeedoff's.....	56	32 $\frac{1}{3}$
A. Yacovleff's.....	0	2
Rastorgouyeff's.....	0	1
Countess Polier's.....	0	27
Total.....	57	26 $\frac{2}{3}$

Produce of Gold and Platina during the last Six Months of the Year 1832.

Gold.	poods.	lbs.
Crown works.....	73	39 $\frac{1}{2}$
Alexey Yacovleff's.....	27	35 $\frac{1}{2}$
Rastorgouyeff's.....	15	31 $\frac{1}{4}$
Demeedoff's.....	18	32
J. Yacovleff's heirs.....	12	35 $\frac{1}{4}$
Tourchaneenoff's.....	3	18 $\frac{1}{4}$
Yartzoff's.....	3	36 $\frac{3}{4}$
Goubin's.....	1	39
Count Strogonoff's.....	1	39 $\frac{1}{4}$
Vsevoloshky's.....	6	28
Countess Polier's.....	0	34
Major's.....	0	17 $\frac{1}{2}$
Gousetnikoff's.....	0	2
Total.....	168	28 $\frac{1}{2}$

Platina.	poods.	lbs.
Private works.....	58	37
Crown ditto.....	0	8 $\frac{1}{4}$
Total.....	59	5 $\frac{1}{4}$

It is to be observed here, that 36 lbs. English, and 40 lbs. Russian, make a pood.

The annexed tables exhibit the increase of gold, silver, and platina coin in circulation in Russia during ten years from 1824 to 1834. This increase has been most rapid, especially in gold and silver, as will appear from the following table of import and export.

¹ A comparative Statement of the Value Sterling of Gold and Silver raised in each of the Mining Countries of America and Russia, as far as the same can be ascertained from the British consular agents in those countries. Ordered by the House of Commons to be printed, 8th March 1836.

Mines.	Value.	Value.
1824.....	Rs. 6,274,543	Rs. 4,792,456
1825.....	11,574,755	1,619,794
1826.....	4,878,460	3,647,974
1827.....	13,736,300	3,611,108
1828.....	15,068,466	2,603,807
1829.....	36,719,937	2,910,345
1830.....	48,516,590	3,452,460
1831.....	44,933,037	4,546,098
1832.....	43,133,287	4,320,104
1833.....	52,080,297	8,222,938
1834.....	19,976,099	8,646,393
Value in B. N. Rs.....	296,911,771	48,373,477

Remaining in the empireRs. 248,538,294

The total amount of gold and platina obtained from the Ural mines during the same years is as follows :—

	poods.	lbs.	zol.
Gold.....	3265	24	77
Platina.....	781	9	61
Gold valued at 50,000 rs. per pood..	Rs. 163,280,000		
Platina.....at 11,520 rs. per ditto..	8,999,712		
Add the above balance of imports...	248,538,294		

Total..... Rs. 420,818,006

But 420,818,006 rubles, at the average exchange of 10½d. per ruble, exceed L.18,375,000 sterling. The above quantities of gold and platina have been coined at the Russian mint; the produce of private mines in the Ural is included in the return.¹

The amount of silver produced during the ten years from 1824 to 1834 by the Altaï and Dauri mines, averaging above 1000 poods per annum, and therefore amounting to 10,000 poods in all, is not included in the above table. Since 1834, a very considerable quantity of gold has been obtained by the washings on the Altaï Mountains. The mines of these mountains occur in the districts of Kolyvan, Zmeof, Tcherepanofsky, Smenofsky, Nicolaisky, Philipofsky, and some others, which, besides gold and silver, produce also a considerable quantity of iron, copper, and lead.

2. Mines of Silver.

The silver mines hitherto discovered in France do not appear to be of any great importance. The mine of Allemont, in the department of the Isère, is situated near the summit of a lofty mountain, composed of beds of gneiss and primitive limestone, inclined in different angles to the west. The veins are numerous, and run in all directions. The ores are native silver, sulphuret of silver, red silver, and a small quantity of muriate of silver; they are accompanied by different ores of cobalt, antimony, nickel, &c.; and the matrix is usually clay mixed with iron, lime spar mixed with asbestos, and some other minerals. Indications of silver have also been observed in the Vosges, where, in a vein of gray copper ore, has been found a certain proportion of this precious metal.

The silver mines of Spain are by far the oldest which are known. They were wrought in the time of the Romans;

and, from the remains of the old workings, it would appear that the operations had been carried on to a great extent. The mine of Guadalcanal, in the Sierra Morena, upon the confines of Andalusia and Estremadura, was formerly very rich, but seems to be now nearly exhausted. The ore which it yields is red silver found in a matrix of compact carbonate of lime.

The mining territory of Freyberg in Saxony abounds with veins of silver, or with lead containing a considerable proportion of that metal. The veins traverse gneiss rocks, and are generally of quartz, lime, and fluor spar; the metallic ores are argentiferous sulphuret of lead, red silver ore, and argentiferous gray copper ore. The richest of the Saxon mines, that of Himmelfürst, is situated two miles south-east of Freyberg. The elevation of the surface above the level of the sea is 1346 feet, and that of the bottom of the mine 263, so that its depth is 1083 feet, or 361 yards. There are five veins in this mine. The principal vein (*teichflache*) is from one foot six inches to three feet in width; the others are from six to twelve inches wide. The direction of this vein is nearly north and south, and its "underlie" is west about three feet per fathom. Some of the other veins intersect it. The ores consist of argentiferous sulphuret of lead, native silver, sulphuret of silver, and red silver; and their produce is from six to seven ounces of silver per quintal of 100 lbs., equivalent to 3¼ or 4½ parts of metal in 1000 parts of ore, or from ⅔ths to nearly one half per cent. The veinstone is quartz, pearl spar, and calcareous spar; and the ores are accompanied by blende, spathose iron, and a little iron and arsenical pyrites. The *Franckenschacht* is 180 fathoms, and the adit at this shaft is 47 fathoms in depth. The quantity of silver ore produced annually is stated at 630 tons, yielding 6160 lbs. troy of silver, valued at about L.18,000. The total cost of the mine is L.9500, and the clear profit of the proprietors L.3500. About 700 miners are employed, of whom 550 work under ground. The ores are delivered to the government reduction works in the neighbourhood of Freyberg, where they are partly smelted and partly amalgamated.

The mines of Schemnitz and Kremnitz in Hungary have long been celebrated, not only for their richness, but also for the immense extent to which the operations have been carried. The rocks traversed by these veins are composed of an argillaceous gray stone, mixed with quartz, schorl, or particles of lime spar, and sometimes called metallic rock. There are three principal veins, the course of which is nearly from north to south; they run parallel to the river Gran, following even the windings of its channel. The dip or inclination of these veins is generally from west to east, at an angle varying from 30° to 70°. One of the capital veins alluded to, called the Spitaler vein, is joined at a particular part by an argillaceous white vein which runs along with it on the hanging side, and from the point of junction the latter is found to produce silver. In this vein Baron Born discovered a petrified porpites or simple madrepore included in sound sinople, a mineral resembling red jasper. This petrification was found at a depth of about eighty-nine fathoms, in a level driven on the vein. The second great vein at Schemnitz exhibits nearly the same general characters as the first in regard to the distribution and nature of its productions. In the hanging side, to-

¹ In the year 1826, when Professor Engelhardt undertook a scientific journey into the Uralian Mountains, he remarked that the sands in the neighbourhood of Koushra, and those at the platina mines at Nijnei-Toura, strikingly resembled the Brazilian sands, in which diamonds are found. Baron Humboldt, during a subsequent residence in the same country, confirmed this resemblance; and examinations having been made, by his advice, a young countryman employed in washing the auriferous sands on the grounds of the Countess Portier, discovered, on the 20th June 1830, a diamond which is nothing inferior to those of Brazil; and soon afterwards many others were found superior in weight to the first. Thus Russia has added this source of riches to those which of late years she has obtained from the gold and platina mines of the Ural chain of mountains (*Revue Encyclopédique*, tom. xlv. p. 460). Emeralds have also, it seems, been discovered, some of them of large size and considerable purity.

Mines.

wards the first vein, it contains lead ores; and on the ledger side there is a layer of clay from one to four feet thick, in which are imbedded nodules of lead ore, yielding from two to five ounces of silver. The third great vein is more irregular in its formation than the two others, sometimes rising vertically, and sometimes dipping in a contrary direction from east to west. The ores of this vein are not very rich in silver, but some of them afford a considerable proportion of gold. This mine appears to have been wrought from a very early period, and the mining operations have been carried to a vast extent. The gallery or level, called the Emperor Francis's Gallery, is that by which the whole of the mines are drained and cleared of water; it is carried through hard rock, and must have been a work of immense labour and difficulty, being about five English miles in length. This gallery was begun in 1748, and finished in 1765. The mountains around Kremnitz are composed partly of the metallic rock already described, and partly of primitive trap. At this place there is also a gold mine established on a large and rich vein, which at the depth of 160 fathoms continued to be productive. The rock is a white solid quartz, mixed with fine auriferous red and white silver ore. There are also mines at Königsberg, a town some miles to the north-west of Schemnitz. The vein is a gray quartz mixed with auriferous pyrites.

The circle of Saaz in Bohemia abounds in various metallic ores, amongst which those of silver greatly predominate. The prevailing rocks are gneiss and argillaceous schistus. The veins at Katherineberg traverse gneiss, and run generally in a north and south direction, parallel to the mountain in which they are situated. But there are also some powerful veins which cross the mountain, particularly one, which seems to be insensibly blended with the mountain rock, and whose ores are rich silver and copper pyrites, with fluor spar, blende, various copper ores, and sometimes native silver and copper. Joachimsthal, a place in the same circle, is also celebrated for its mines. The prevailing rocks are gray, micaceous, and quartzose clay slate, and the surrounding mountains have a gentle declivity towards the south, but run in lofty ridges to the east, north, and west, and are intersected by deep valleys; an inequality of surface which enables the miners to open numerous galleries converging to the south, and also towards the valley in which stands the town of Joachimsthal. The whole galleries and works of this district are divided into six different fields, and are drained by two deep drifts or levels; one of these runs in a direct line 1600 fathoms, and, including its several branches, is 4500 fathoms in length; the other runs in a direct line 1500 fathoms, and its total length extends to 5600 fathoms. The depth of the former under the summit of the mountain is 170, and that of the latter 190 fathoms; but the operations in the mines have been carried to a much greater depth; indeed, excepting those of the Tyrol, they are considered as amongst the deepest in the world. The metallic veins of this mining district are disturbed by dykes of red porphyry or trap, called by the miners *combs*. The course of these dykes is very irregular, and their thickness varies from a few inches to forty fathoms; they also unite with metallic veins, and, either running parallel or crossing them, improve, disturb

their course, or render them barren. It has been observed that those dykes which run from north to south commonly disturb the course of the metallic veins, which they traverse in a contrary direction. A dyke of this description, crossing one of the principal veins of the district, was discovered on the sole of one of the great levels, where the thickness was not less than from thirty to forty fathoms. At this place, which is 150 fathoms below the surface, and 3000 fathoms distant from the door of the gallery, an entire tree was discovered.¹ The thickness of the veins varies from one inch to two feet, and the veinstones are a whitish or bluish clay, argillaceous slate, and reddish hornstone or petrosilex. The ores found in this district are, native silver, vitreous silver ore, red silver ore, and white silver ore. The silver mines of Berestadt were formerly rich in native silver, and other ores of that metal.

The silver mines of Stahlberg in Sweden are situated about twenty-eight English miles from Upsal. The ore is an argentiferous galena, in a compact limestone, and produces a marc or a marc and a half of silver per quintal. These mines have been wrought to the depth of 150 fathoms; and the annual profits at an average amount to about L.4000, of which one eighth is paid to the state. The silver mine of Königsberg in Norway is represented as much richer than any of those in Sweden. The mountains are composed of strata nearly vertical; their general direction is from north to south, with an inclination towards the east; and they are generally parallel to each other, but sometimes take a wavy or zigzag course. Some of the strata are composed of mica mixed with garnets and lime spar; others consist of a grayish-white quartz mixed with fine black mica, a little carbonate of lime, and reddish hornstone; some are composed of alternate layers of quartz and mica, and others of a ferruginous rock. The veins cut these strata transversely, and are from half an inch to two feet and a half in thickness. The ores are chiefly native silver, enormous masses of which have sometimes been found,² vitreous silver ore, and occasionally red silver ore and galena. The matrix of the ore is granulated limestone, sometimes foliated or mixed with fluor spar and oxide of iron. This mine is most productive in that part where the veins traverse the strata of ferruginous rock. The greatest depth to which the operations have been carried is about 160 fathoms, and the annual produce was at one time nearly 5000 lbs. of silver.

We have already, under the former head, adverted to the mineral riches of that part of the Altaï chain of mountains which is included in Asiatic Russia. The silver mines of Zmeof are situated between the rivers Obi and Irtisch, in a tract extending from 50 to 52 degrees of north latitude. The annual produce of these mines is stated at 60,000 marcs of silver, which is alloyed with about three per cent. of gold. The mines of Nertschink in Dauri or Daouria, near the river Amur, yield argentiferous galena, producing annually about 36,000 marcs of silver, containing about one and a half per cent. of gold.

3. Quicksilver Mines.

The continent of Europe, so rich in almost every species of mineral produce, contains also large stores of quick-

¹ At the time when this discovery took place, the tree in question was supposed to be a production of the antediluvian world. The exterior appearance, the fibrous structure, the concentric circles, the ramification of the substance into round branches, the soft unpetrified bark which adhered to them, and something like leaves found in different parts of it, left no doubt, in the minds of those who had an opportunity of observing it, that it was a vegetable production converted into stony matter. Its specific characters, in as far as these were observed, have not been stated. The tree found in Craigleith quarry, also at a great depth below the surface, was supposed to have belonged to the coniferous species. Soon after the discovery of the former, part of the level gave way, and the water increasing, rendered it impossible afterwards to examine the spot.

² Of these one is mentioned which is said to have weighed more than 220 lbs.

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Mines. silver, but limited apparently to a very few favoured spots.¹ The ores of this metal exist in various states, as in that of native mercury, alloy, or amalgam; in that of sulphuret or cinnabar, which is sometimes impregnated with a bituminous clay; and in that of salt, or muriate of mercury. The ores of mercury are but rarely met with in primitive mountains, the greater proportion being found in secondary rocks, as in bituminous schistus, compact limestone, ferruginous sandstone, and sometimes even in ferruginous clay; and these ores are usually distributed in large confused masses, seldom in regular veins. The metallic ores which usually accompany those of mercury are sulphuret of lead, sulphuret of zinc, hæmatites, iron pyrites, silver, and various ores of copper.

The principal mines of quicksilver on the continent of Europe are those of Almaden in Spain, Idria in Carniola, and the Palatinate, or that part of the Bavarian dominions which is westward of the Rhine.

Mines of Almaden.—The most ancient mine of quicksilver known in the world is that of Almaden in Spain. According to Pliny, it was wrought five hundred years before the commencement of the common era; and in his time 10,000 lbs. of cinnabar (sulphuret of mercury) were transported to Rome, for the purpose of being employed in painting. This celebrated mine, or rather cluster of mines, is situated in a branch of the Sierra Morena, upon the confines of Andalusia, about fifteen leagues to the north of Seville. The hill which contains it is about a thousand fathoms in length, six hundred in breadth, and a hundred and twenty in height. It is composed of the same materials as the neighbouring mountains, which consist of sandstone; and its surface exhibits two inclined planes, which, uniting at the summit, form a crest of rock, that is entirely bare, and spotted with sulphuret of mercury. The village of Almaden, from which the mines take their name, is built chiefly on the cinnabar itself. The two principal veins, which traverse the mountain longitudinally and intersect it vertically, are from two to fourteen feet in thickness, and throw out branches in different directions; but towards the middle of the mountain they unite, and form a mass of mineral about a hundred feet in thickness. The veinstones are of the same sandstone as that of which the mountain itself is composed. The more finely-grained matrix affords the greatest quantity of cinnabar; and some of the ore is so extremely rich as to yield nearly ten ounces of mercury in each pound; but from other ores only three ounces can be extracted. The sides of the vein are formed of a black slate in a state of decomposition, and frequently contain a good deal of cinnabar, as well as large, round, and flat masses of pyrites, exhibiting internally some spots of cinnabar. In other parts, there have been discovered veins of aluminous schistus and iron ore, running in the same direction with the mountain, and yielding specimens of ore, in which the iron, the sulphur, and the quicksilver are found closely combined. This fact, which has been noticed in other mines of mercury, shows that nature sometimes produces combinations which cannot be effected by any known process of art. Previously to the year 1752, the annual produce of the mines of Almaden amounted to be-

tween 5000 and 6000 quintals of mercury, which was exported to Mexico for the purposes of amalgamation, in extracting gold and silver, particularly the latter, from their ores. About that period, the quicksilver mines of Guancavelica in Peru being nearly exhausted, the mercury required for amalgamation in South America was exported from Almaden; so that the annual amount of quicksilver extracted from this grand reservoir increased from 6000 quintals to 16,000, 18,000, and even 20,000 quintals. At the present day, the mines of Almaden continue to be by far the most productive in the world.

Mines of Idria.—The celebrated quicksilver mines in the vicinity of Idria, in Carniola, are situated about eight leagues from Trieste, on the boundary of the province of Friuli. The town of Idria, which gives name to the mines, stands in a deep valley which is surrounded by lofty mountains of limestone, and exhibits a dark-coloured slate included between two beds of limestone, rising to the surface at an angle of from 45° to 75°. The ores, consisting of native mercury and cinnabar, are deposited in this schistus, which is about sixty feet thick, and of very considerable extent. The position of the metalliferous stratum is variously inclined, and sometimes horizontal. The depth of the principal shafts by which the ores are brought up exceeds 120 fathoms. The colour of the schistus from which the ore is obtained varies in different parts of the mine. When it is of a whitish hue, it is poor in metal, but when the colour changes to a blackish shade, the ore yields about sixty per cent. The metallic bed is sometimes intersected by vertical strata, which, according as they are hard or soft, produce opposite effects; for, in the former case, the ore in a great measure disappears, but when they are softer and more brittle than the metalliferous bed itself, the ore becomes more abundant. In some places there occurs a hard slaty rock, containing small shining globules, and yielding little more than two per cent. of quicksilver, called *coral ore*; and in others there are found small veins of coal impregnated with ore, and affording about the same proportion of pure mercury. The mines of Idria were discovered in the year 1497. The mountain in which they were first established has been exhausted, and the operations are now carried on in an opposite mountain, whence, it is said, a supply of mercury to almost any extent might be obtained; but the quantity extracted is limited to between 3000 and 4000 quintals, which are mostly retained for home consumption, being used for the amalgamation of the gold and silver ores, which are found in greater abundance in the Austrian states than in any other country in Europe, except Russia, which, however, derives part of her supplies from her Asiatic dominions.

The following particulars respecting the mines of Idria are extracted from Silliman's *Journal*, to which they appear to have been communicated by an officer of the American navy, who had made a pedestrian tour through Germany, and had, in the course of his travels, visited Idria.

"The mines have nothing corresponding to the ideas of terror which we are apt to connect with such places, except the atmosphere, which throughout the mine must be strongly impregnated with mercurial vapour, and is con-

¹ It appears rather singular that a country so rich in almost every variety of mineral produce as Great Britain should be entirely destitute of quicksilver, more especially as the coal formation, in which that metal is most commonly found, is here so largely developed. There is, however, a passage in Bishop Watson's *Chemical Essays*, in which he mentions the circumstance of quicksilver having been found in a native state at Berwick-upon-Tweed; and the same thing is stated in the *Commercial Magazine* (vol. ii. p. 204), and also in Williams' *Natural History of the Mineral Kingdom* (vol. ii. p. 378). This discovery is said to have been made in digging out clay for the foundation of a house in the street called Hyde Hill, in the town of Berwick; and it appears to have taken place more than half a century ago. The clay being dug out, lay for some time where it had been deposited, and the mercury was observed to exude from the small fissures or cracks which were formed in it as it dried, being apparently distributed throughout the whole mass of the clay. Many years afterwards, when some workmen penetrated into the same bed of clay, it appeared to be impregnated with mercury, which ran out in small globules. It is remarkable that so important a mineralogical fact did not attract more attention, and lead to some examination of the bed of clay, which appeared to be thus impregnated with quicksilver in the native state.

Mines. stantly producing salivation amongst the workmen. Having descended by 727 steps, reaching to a depth of 120 fathoms, we arrived at the region where the cinnabar is chiefly procured. The mining operations are chiefly carried on in galleries, the friable nature of the rock seldom admitting of larger chambers. The cinnabar is in strata of from two to six inches in thickness, and of a variety of colours, from dark to light red, the quicksilver being sometimes mixed with it, and sometimes occurring in the intervening strata of earth or stone. Sometimes the cinnabar is of a brilliant red, and once I found it in small crystals, but such specimens are rare; it is generally of a dull red colour, and the stone is so brittle, that nothing more than a pickaxe is required. The strata affording the quicksilver appear to have no particular direction, and occupy about one third or one half of the entire mass of the rock. Proceeding a short distance, however, we came to the galleries where the cinnabar is less common, and the quicksilver is the chief object of search. It occurs here sometimes imbedded in a friable rock, sometimes in a kind of earth in appearance and hardness resembling talcose slate, but principally in the former. Generally it is in particles too minute for the naked eye, but often when the rock is broken small globules present themselves, varying from a size just large enough to be seen, up to that of a common pin's head. These globules are not distributed at random throughout the mass, but the substance in which they occur forms strata usually about one inch or two in thickness."

The traveller, descending still lower, soon came to the richest part of the mine. Here the gangue or matrix consists almost entirely of talcose earth, and the globules are so large that when it is broken they roll out and fall to the bottom of the gallery. The labourers are relieved every four hours, being unable, from the state of the atmosphere, to work longer than this at one time. In the other parts of the mine they work eight hours. The total number employed in the mine is 360, divided into three companies, each of which works eight hours. Their pay is only from fifteen to seventeen kreutzers a day, the usual pay of day-labourers in Germany. Several of them appeared to be suffering from the effects of the mercury. Having returned to the upper mine, the traveller next proceeded to examine the washing-rooms, which are situated a few hundred yards from the mines.

"The gangues containing the metal are carried to this house; and if the ore is of the earthy kind, it is broken up, and thrown upon large sieves, by means of which the loose or native quicksilver, called here *jungfrau*, or virgin quicksilver, is separated from the earth; the latter is then cast into shallow boxes, open at the ends and a little inclined, and a gentle stream of water being made to pass over it, a rake is used, and the earthy matter is carried off. There are seven of these boxes in succession, and by the time the residuum reaches the last of them, it resembles a heavy gray powder, and is sufficiently pure to be carried to the vapour furnace. The stony fragments require only a slight washing to cleanse them from the outward earthy impurities.

"The furnace is half a mile lower down the valley, and at the extreme end of the village. It consists of a circular walled building, about forty feet diameter by sixty in height, on each side of which there is a continuous range of chambers ten or twelve feet square, and nearly as many in height; by means of small square openings in the partition walls, the air is allowed to pass from the centre building to the remotest. Each has also a door communicating with the external air. These buildings are all of stone, and are plastered within. The gangue, after being prepared in the washing-house, as already described, is removed to this edifice, and placed in earthen pans four

inches deep and fifteen in diameter, which are piled up so as to fill the centre building. The doors of the chambers are then carefully walled up; and a strong fire having been lighted under the centre building, the quicksilver rises in the form of vapour, and passing into the small chambers, is there condensed by the cold atmosphere around them. Some of the gangue is brought here in the form of the native rock. The expansive power of the vapour, together with the heat of the fire, is sufficient to cause the rock to disintegrate, and thus to allow the escape of the quicksilver. When this process is over, the doorways of the chambers are once more opened, and the quicksilver, which is found chiefly adhering in drops to the sides and ceiling, is scraped off, and running into a hollow in the floor, is taken thence to the cleaning and bottling room. It appears to act on the mortar of the chambers, for I found the latter flaky, and the crevices all filled with small globules.

"The cleaning process is very simple, a piece of canvass being merely spread over a funnel, and the quicksilver being made to pass through this, comes out sufficiently pure. That intended for home consumption is then tied up in sheep-skins, while that for exportation is put in iron bottles, large enough to contain sixty-eight pounds. The furnace is kept in operation only during the winter months, and then the vapour which escapes from it is a serious annoyance to the town; they have a blast three times every fortnight."

Mines of Bavaria.—Extensive, but now almost neglected, mines of quicksilver, have long been wrought in that part of the Bavarian dominions which is westward of the Rhine, and anciently formed the Palatinate. These mines are situated in the mountainous country to the south of Kreuznach, a town on the southern frontier of the Prussian territory, and they lie chiefly between that place and Wolfstein. This elevated range forms the northern prolongation of the primary chain of the Vosges, and rises to its greatest altitude in the porphyritic summit of the Donnersberg or Mont-Tonnerre. They are entirely within the Bavarian dominions, being in the immediate vicinity of Bingart, Nieder Moschel, Ober Moschel, and Alzens. They are stated to have been worked for about five centuries; and both the excavations below, and the immense piles of attle on the surface, prove that some have been wrought to a considerable extent. The working indeed has never been given up for any length of time; but this part of Germany having been the theatre of the early campaigns of the French revolutionary army, the mines were for a time suspended, and have never since been effectually resumed. Prior to this period their produce must have been considerable, as they were reported, by a commission of French engineers, to have yielded annually 67,000 lbs. of quicksilver.

The deposits of quicksilver are chiefly worked in the sandstone formation, but in some places these appear to extend into the slate. The sandstone is of a pale brownish or grayish colour, usually very compact, and approaching the nature of hornstone. In some of the mines, strata of a much softer description, and of an argillaceous nature, are contained in the sandstone. The quicksilver occurs neither in a bed nor in a vein, but forms rather what may be termed a metalliferous channel of ground, of considerable breadth and extent. The direction of these channels approaches that of north and south, but in some mines there are two or more crossing one another. Their breadth is quite undefined, but they are worked from five to six feet in width, and appear to descend almost perpendicularly into the rock. In these channels exist thin fissures, called *klefts*, which, although in themselves unproductive, seem to be chiefly depended upon by the miners in guiding their researches. The quicksilver is mostly found in the joints of the rock, which, in the vicinity of the *klefts*, appear to

Mines. be more or less filled with it to an indefinite extent; but whether it is of contemporaneous formation with the rock, or deposited in cracks which had subsequently opened in it, has not been ascertained. The depth to which the quicksilver extends is also unknown, but none of the mines in this district exceeds 300 feet in depth. The ore is cinnabar, which varies from a bright to a dull red colour, traversing the mass of the rock in all directions, sometimes very abundantly; but its distribution does not appear to follow any general law, or to be exclusively limited to any particular strata. Rich specimens often occur, containing, along with cinnabar, a good deal of native quicksilver disseminated in small globules; but these bear a very small proportion to the poorer ores, or rather the masses of rock containing thin veins of cinnabar. Rich stones of ore, such as are often found in the more productive parts of the deposits, yield from five or six to eighteen or twenty per cent. of quicksilver, and picked specimens as much as fifty or sixty per cent.; but, taking the general average of the stuff raised from the mines, the produce does not probably exceed three per cent.

In the vicinity of Bingart the mines are situated on the declivity of the mountain, at an elevation of about a thousand feet above the valley, and are consequently worked chiefly by adits, which enter the mines at depths varying from twenty to thirty lachters. In some of the mines the workings above the adits are considerable, and "sinks" have penetrated to a depth of nearly twenty lachters below. These mines have been opened chiefly in the sandstone, but one of them appears to extend into the slate.

The Stahlberg mine is situated near Ober Moschel. It is very ancient, and has been extensively worked, the depth being near 300 feet, and the longitudinal extent of the excavations considerable. It is situated on elevated ground, and drained by an adit, which is driven into the workings nearly at the deepest point; but there are no shafts, access being afforded by levels driven into the side of the mountain. The mine is still worked to some extent, and produces a good deal of cinnabar. The prevailing rock is a compact sandstone or hornstone, occasionally containing softer argillaceous strata. The great magnitude and extent of the excavations, and the very peculiar manner in which they have been formed, render the appearance of this mine exceedingly picturesque. The excavations consist of a series of irregular chambers fantastically over-arched, and communicating with one another. The height is often considerable, and the width is in some cases twenty or thirty feet. The access to these chambers, and also from one to another, is by rude staircases hewn out in the solid rock, thus furnishing a novel and easy mode of subterranean communication. The unusual light and the broad shadows produced by the lamps of the miners, the spacious but irregular excavations, and the perspective of the rude winding steps by which the various chambers of the mine are entered, form altogether a striking and picturesque scene. See the annexed sketch.



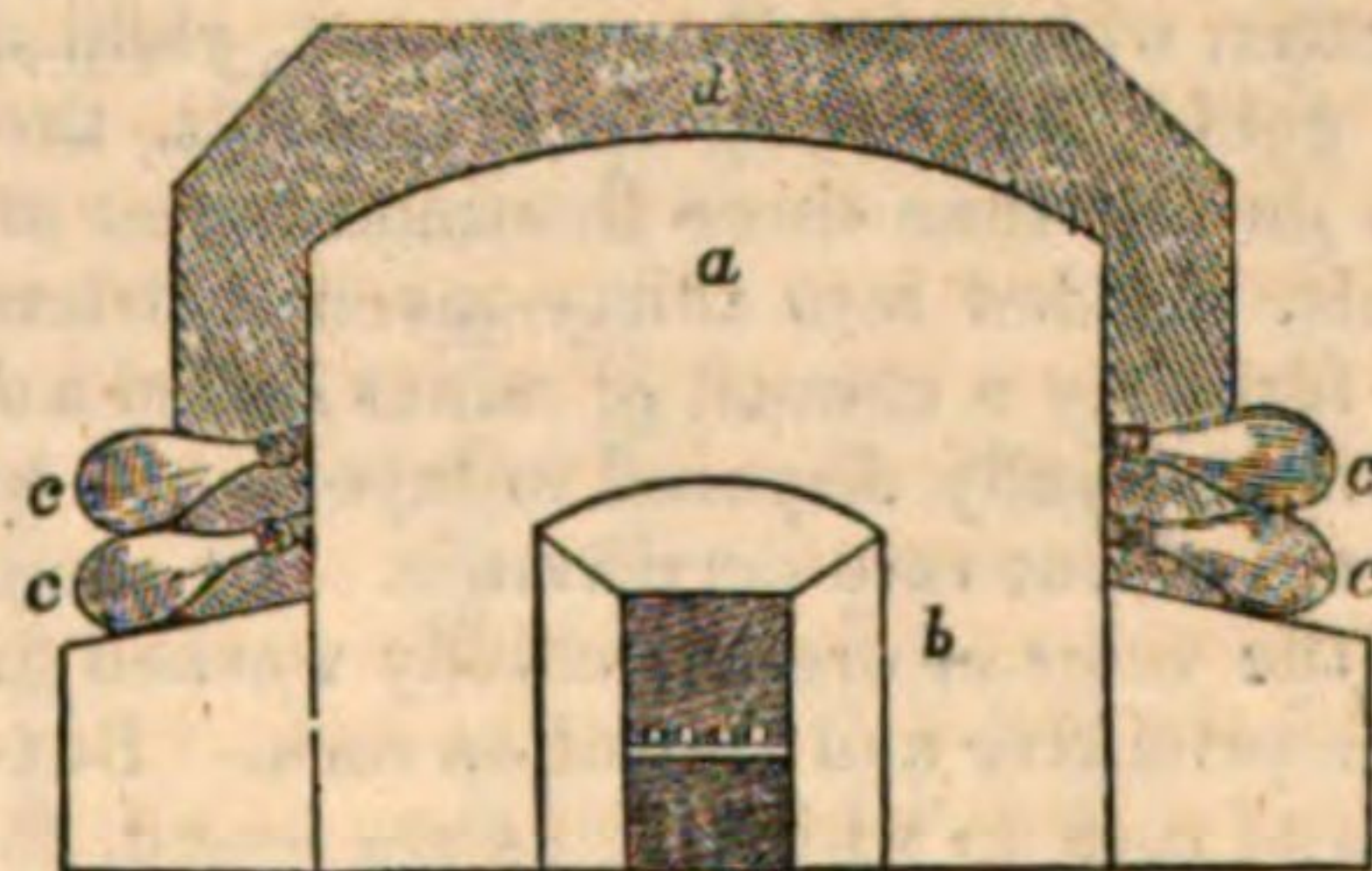
Mines. The present operations are chiefly confined to breaking down old pillars and masses of rocky ore left standing in various parts of the mine; and even from these sources considerable produce is obtained. The cinnabar is generally disseminated throughout the rock, but abounds rather more in some strata than in others. The miners here are but little affected by the mercurial vapours, owing to the spaciousness, dryness, and good ventilation of the workings, with the easy mode of access to them.

The Landsberg mine is about three miles distant from that of Stahlberg, being situated on the declivity of a lofty mountain, covered with wood, and crowned with the ruins of an ancient castle. It is equally extensive with the Stahlberg mine, and has been worked in a similar manner, although at present the operations are carried on upon a limited scale. The mode here practised of reducing quicksilver is one of the simplest operations in metallurgy, consisting merely in a process of distillation.

The furnace in which it is performed is about twenty-four feet in length, twelve in breadth, and six or seven in height; fires are placed at each end, and the heat, passing first through the body of the furnace, goes off by a cross-flue in the middle. Forty-eight iron retorts, twenty-four on each side, are arranged in the interior of the furnace, in two rows one above the other, so as to be exposed to the heat in its passage from the fires to the cross-flue in the middle by which it escapes; and the necks of the retorts pass through apertures in the wall, so that smaller retorts upon the outside of the furnace can be luted on to them. This will be better understood by reference to the annexed sketches, the first of which represents an end view, and the second a cross section of the furnace.

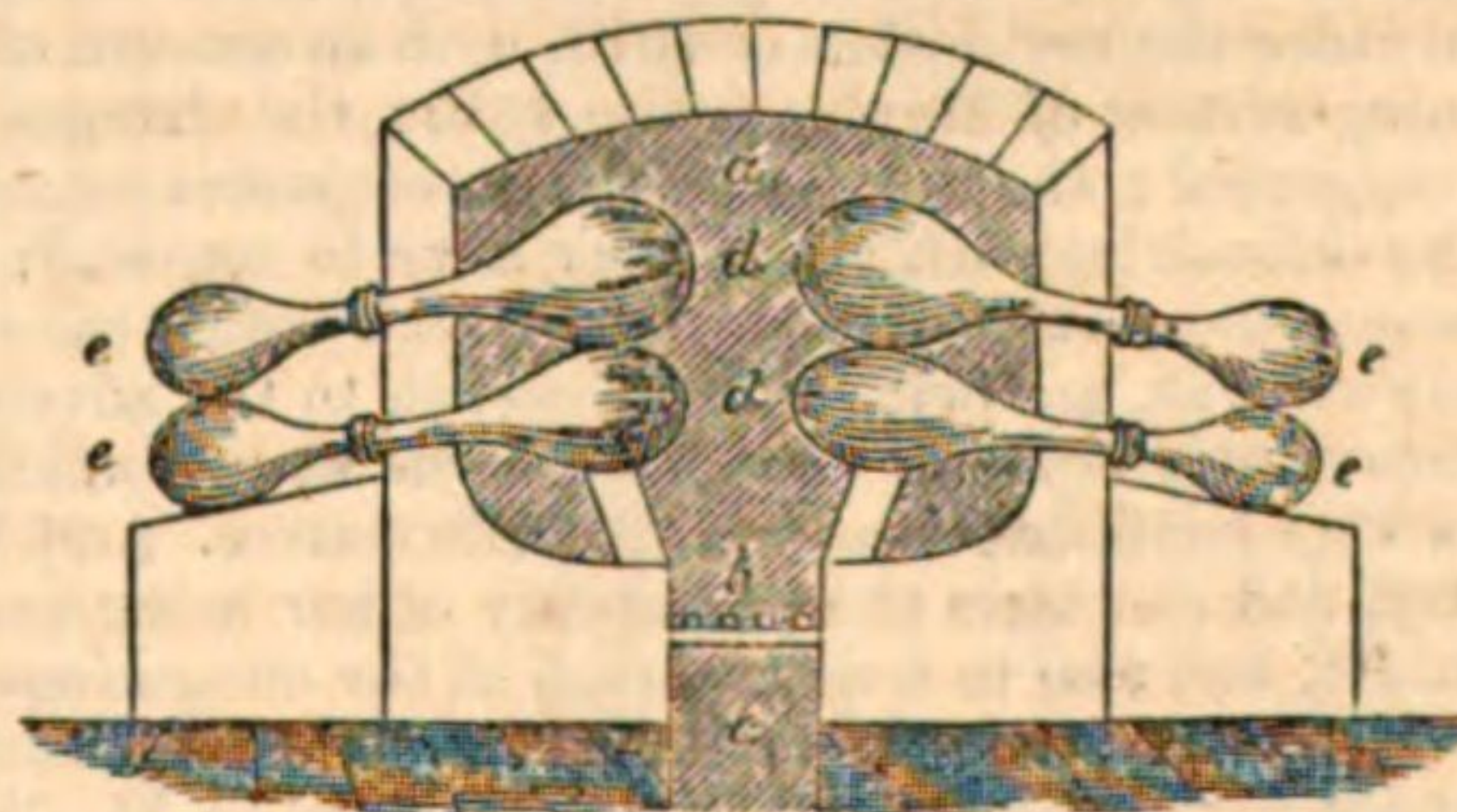
In fig. 1, *a* represents the body of the furnace exteriorly, *b* the fire-place, *c* the outer set of retorts arranged in two rows one above the other, and *d* the cross-flue in the middle, thus:

Fig. 1.



In the cross section, fig. 2, *a* represents the body of the furnace interiorly, *b* the fire-place, *c* the ash-pit, *ee* the small retorts placed outside the furnace to receive the mercurial vapour, and *dd* the large retorts arranged in the body of the furnace in which the ore is exposed to heat, thus:

Fig. 2.



From this explanation of the construction of the furnace, the process of reduction will be easily understood. The ore, after being carefully picked and broken, to separate the worthless matter, is put into the large iron retorts, together with a certain quantity of pulverized lime,

Mines. and exposed to a moderate heat, which soon drives off any moisture that may be contained in it. The outer set of retorts is then luted on, and a much stronger heat applied, which, being continued for several hours, at length volatilizes the quicksilver, and drives it in the form of vapour into the small retorts outside, where it soon becomes condensed, and assumes the metallic form.

The Bavarian mines are now in the possession of an English company, and are therefore likely to be worked with spirit and success. They possess the advantage of being drained to a great extent by levels, and are therefore almost free from water, whilst coal for the reduction of the ore may be obtained in their immediate vicinity. From the nature of the deposits, it appears that they are capable of yielding an immense mass of rock more or less impregnated with quicksilver; and from the ease with which this produce may be obtained, and the occasional richness of some portions of the mass, these mines appear to offer a very fair field for enterprise.¹

Near Selvena, in the territory of Sienna, in Italy, cinnabar has been discovered; it is distributed in irregular masses, and forms thin veins in a clay mixed with argillaceous marl, but does not appear to be of much importance. There are two mines of mercury at Zalathna, in Transylvania. The ore of the one is cinnabar, which is extracted from a vein in a matrix of quartz and lime spar, traversing a black argillaceous slate and sandstone. The ore of the other mine is granulated cinnabar, included in a vein which runs in limestone. The annual produce of these mines amounted, according to Baron Born, to about 6000 lbs. of pure quicksilver.²

IV.—MEXICAN MINES.

Mexico, although it contains a variety of metals, as iron, lead, copper, tin, zinc, antimony, arsenic, and manganese, is chiefly celebrated for its gold and silver mines, particularly the latter, which, for the most part, yield also a proportion of gold. According to Humboldt, there are in New Spain no less than three thousand mines of the precious metals, divided into thirty-seven districts, each of which had formerly a council of mines called a *deputation*. The ores are generally disposed in layers, and masses are comparatively of but rare occurrence. At present, in all the mines, the veins of ore are chiefly worked; and these occur in the primitive and transition rock. But of the different kinds of rock in which veins are found, the porphyries are considered as affording the richest ore. At the beginning of the present century, Humboldt conjectured that, in the northern part of Mexico, particularly in the Sierra

Madre, great mineral wealth would be discovered in the rocks of secondary formation; and this conjecture has been confirmed by subsequent inquiry and examination. "The Sierra Madre," says Mr Ward, "has been traversed seven times between Oaxaca and Chihuahua, by a very spirited and intelligent English traveller, Mr Glennie, whose opinion of its riches confirms all that had been surmised in earlier days; and his conviction of the advantages to be derived from mining speculations in that direction has induced the directors of the United Mexican Company to entrust him with the formation of an establishment at Jesus Maria (one hundred leagues west of Chihuahua, upon the slope of the Sierra Madre), which I consider as a step towards that revolution in the mining affairs of Mexico, the probability of which, in the course of twenty or thirty years, I cannot but look forward to."³ The gold and silver ore obtained in Mexico being much more remarkable for its abundance than its richness, there can be little doubt that if the layers and veins of the Sierra Madre should prove much more productive than those which have been worked upon the table-land, the consequence must be such as Mr Ward has anticipated.

The great mining districts of New Spain, arranged according to the proportional quantities of silver which they yield, have been classified by Humboldt thus:—Guanaxuato, in the intendency of the same name; Catorce, in the intendency of San Luis Potosi; Zacatecas, in that of the same name; Real del Monte, in the intendency of Mexico; Bolaños, in that of Guadalajara; Guarismey, in the intendency of Durango; Sombrerete, in that of Zacatecas; Tasco, in the intendency of Mexico; Batopilas, in that of Durango; Zimapan, in the intendency of Mexico; Fresnillo, in that of Zacatecas; Ramos, in the intendency of San Luis Potosi; and Parral, in that of Durango. But, from various causes, particularly the suspension of mining operations consequent on the revolution of 1810, and still more from the recent application of British capital to the working of the Mexican mines, this arrangement would require certain modifications to render it, in all respects, applicable to the actual circumstances of New Spain. At the beginning of the present century, for instance, the richest of all the Mexican mines was that of Valenciana; but at the present time the most productive mines are those of Veta Grande. To exhibit a view of the change which, from whatever cause or causes, has since taken place; to indicate results which can only be appreciated in juxtaposition; and, at the same time, to convey, in a condensed form, other information which can scarcely fail to prove interesting; we shall here introduce a comparative table, showing at one view the points both of similarity and of contrast in these two celebrated mines.

¹ Mining Review, No. IX., pp. 9, 10, et seq.

² Born's Travels, p. 120.

³ Mexico in 1827, vol. ii. p. 135. Mr Ward's work, here referred to, will be found to contain the most ample information on the subject of the mines of Mexico. He has treated the subject in four sections, embracing almost every point of any importance connected with it. In the first he gives a comparative statement of the produce of these mines during a double term of fifteen years before and since the revolution of 1810, with an account of the exportation of specie during the same period. The second section treats of the mining system of Mexico before 1810; the changes which occurred from that time till 1823, when the idea of foreign companies was first suggested; the number of these companies established in Mexico; the extent of the undertakings in which they are engaged; the difficulties with which they have to contend; and their progress and condition in 1827. In the third, Mr Ward discusses the question, whether the large capitals which have been invested in the mines by British subjects are likely to be productive of adequate returns, and within what period, to the adventurers; and also whether those returns are likely to make the general produce of the country equal or even exceed the annual average amount derived from the mines before the year 1810; to each of which he gives a very confident answer in the affirmative. And, in the last section, he makes some general observations on Mexico as a mining country, and considers the probability of her being enabled, by her mineral treasures, to multiply her commercial relations with Great Britain, and also to acquit herself of the obligations arising from loans contracted in that country. Much of the information contained in these sections is, no doubt, purely commercial; but there is also a great deal which has an immediate relation to the subject under our immediate consideration; and in Mr Ward's Personal Narrative there will also be found many interesting details respecting the principal mines and mining districts of Mexico.

At present the richest Mines in Mexico.

Four miles north of Zacatecas.
Elevation of the surface above the level of the sea supposed to be about 6000 feet. Elevation of the bottom of the mine above the level of the sea probably near 5000 feet.

Transition clay slate, alternating with dolomite, and occasionally with greywacke. This clay slate is sometimes decomposed; it rests on syenitic rocks, and is in some places covered with porphyry.

One principal vein (the *Veta Grande*), which is generally separated into three branches, and sometimes into four. When ramified, the width extends to 60 or 70 feet; when united, it varies from 8 or 10 to 20 or 30 feet. The branches are generally about 10 or 12 feet wide, and the upper one is most productive. The direction of the *Veta Grande* is from 30 to 40 degrees south of east and north of west, and its underlie from two to three feet per fathom south. Other veins of less size occur in the neighbourhood of the *Veta Grande*, which cross it at an acute angle. One of these appears to heave the vein for about 700 feet, being the most remarkable derangement of the kind on record.

Chiefly red silver, native silver, sulphuret of silver, and argentiferous pyrites.

3½ oz. per quintal.

Chiefly quartz, occasionally amethyst, carbonate of lime, and sulphate of barvtes.

The ores are generally accompanied by blende, sulphuret of antimony, and iron pyrites.

Tiro General, 182 fathoms; *Gallega* shaft, 138 fathoms.

There is no adit to this mine.

About 80 gallons per minute.

On an average about 150 fathoms.

Usually 10 malacates.

32 horses constantly working, or a total number of about 100 horses.

L. 20,000 per annum.

21,380 tons of silver ore.

153,000 lbs. troy of silver.

L. 423,400 per annum.

L. 252,170 per annum.

L. 171,240 per annum.

L. 130,000.

Nearly L. 700 per cent. after paying back the original capital.

About 59½ per cent.

About 900, of whom nearly 600 are employed under ground.

About 8 or 9 shillings per day.

Chiefly reduced by the company, at the hacienda of Saucedo, by smelting and amalgamation.

Richest of the Mexican Mines at the beginning of the present Century.

One mile north of Guanajuato.

Elevation of the surface above the level of the sea 7617 feet. Elevation of the bottom of the mine above the level of the sea 5730 feet.

The *Veta Madre* of Guanajuato, upon which this mine is worked, traverses both clay slate and porphyry, but is most productive in the former rock. The clay slate is considered by Humboldt to belong to the transition class, but situated near the limits of primary formations. This rock in depth passes into chlorite slate and talc slate. It contains subordinate beds of syenite, hornblende slate, and serpentine. The porphyry rests upon the clay slate, and is conformable to it both in direction and stratification.

One veta (the *Veta Madre*), which is often separated into three branches, extending from 130 to 160 feet in width. When not ramified, its width varies from 20 or 30 to 60 or 70 feet, but is more commonly from 40 to 50 feet. The direction of the vein is north-west and south-east; its underlie is south, and about five or six feet per fathom.

Sulphuret of silver, native silver, prismatic black silver, red silver, native gold, argentiferous galena.

Four ounces of silver per quintal of 100 lbs., equivalent to 2½ parts of metal in 1000 of ore, or ¼th per cent.

Quartz, amethyst, carbonate of lime, pearlspar, and hornstone.

The ores are accompanied by blende, spathose iron, copper, and iron pyrites.

Tiro General, 310 fathoms.

There is no adit to this mine.

The Valenciana was a dry mine from its commencement in 1760, to 1780, when it first became troubled with water, in consequence of some of the workings being inadvertently communicated with the adjoining mine of Tepeyac; which, although upon the same vein, was extremely wet. The quantity of water raised during the late working appears to have been about 110 gallons per minute, but the regular influx was much less.

310 fathoms.

A steam engine of 30-inch cylinder, and 7 malacates.

65 horses constantly at work, or a total number of about 200.

About L. 40,000 per annum.

32,500 tons of silver ore.

221,900 lbs. troy of silver.

About L. 600,000.

L. 197,990 per annum.

L. 118,750 per annum.

Cannot be ascertained, but known to have been very small.

Not known, but certainly many hundred per cent.

Costs 60 per cent. In the nine years following, the proportion

was 80 per cent.; at the end of that time the working of the mine

was stopped, by the revolution in the year 1809.

3100 Indians and Mestizoes, of whom 1800 are employed under ground.

From 4 to 5 shillings.

1420 cwt.; value L. 15,830.

Sold to the *Rescatadores*, and reduced by smelting and amalgamation at haciendas, in the neighbourhood of Guanajuato.

Average year at the end of the eighteenth century.

Mines.

That part of the mountains of Mexico which produces the greatest quantity of silver is situated between the parallels of 21° and $24^{\circ} 30'$. The celebrated mines of Guanajuato are not more than ninety miles distant from those of San Luis Potosi. From the latter to Zacatecas the distance is 102 miles; from Zacatecas to Catorce, 93 miles; and from Catorce to Durango, 222 miles. It is not a little remarkable that the sites of the metallic wealth of Mexico and Peru are, in the two hemispheres, nearly equidistant from the equator.¹ The greater part of the gold of Mexico is found in the veins of silver ore, either native or mixed with silver, from which it is separated by washing; the proportion being seldom more than $1\frac{1}{2}$ ounce in the 100 lbs. The silver supplied by the veins of this country is extracted from a great variety of ores, which, from the nature of their mixture, bear some analogy to those of Saxony, the Hartz, and Hungary. The greatest quantity is derived from the sulphuret of silver, from arsenical and antimonial gray copper, from muriate of silver, from prismatic black silver, and from red silver ore. Amongst these ores we do not include native silver, because it is not found in sufficient abundance to form any considerable proportion of the total produce of the Mexican mines. Sulphuret of silver and black prismatic silver are common in the veins of Guanajuato and of Zacatecas, as well as in those of Real del Monte. The richest gray copper ore is that of the Sierra de Pino, and the mines of Ramos. The antimonial gray copper ore is found at Tasco, and in the mine of Rayas, south-east from Valenciana. The muriate of silver, which seldom occurs in the veins of Europe, is very abundant in the mines of Catorce, Fresnillo, and the Cerro San Pedro, near the town of San Luis Potosi. That of Fresnillo is frequently of an olive-green, passing into a deeper shade of the same colour. In the veins of Catorce the muriate of silver is accompanied with molybdate and phosphate of lead. The red silver ore constitutes a principal part of the wealth of Sombrerete, Cosala, and Villalta, in the province of Oaxaca; and from the famous mine La Veta Negra, near Sombrerete, more than 425,000 lbs. troy of silver have been extracted in the space of little more than six months. The true white silver ore is very rare in Mexico; but its grayish white variety, rich in lead, is found in the intendency of Sonora, where it is accompanied with argentiferous galena, red silver, brown blende, quartz, and sulphate of barytes. The martial pyrites found at Pachuca yields as much as three marcs of silver to the hundred-weight of ore. In some parts the operations of the miner are directed to a mixture of brown oxide of iron and native silver, disseminated in particles imperceptible to the naked eye. This ochreous compound formed the object of considerable operations at the mines of Angangueo, in the intendency of Valladolid, and at Yxtepxi, in the province of Oaxaca.

Native silver is much less abundant in America than is generally supposed; yet it has been found in considerable masses, sometimes weighing considerably more than 400 lbs. avoirdupois, in the mines of Batopilas, in New Biscay. In the veins of Mexico, as well as in the mountains of Europe, native silver is constantly accompanied by *glaserz* or prismatic silver, particularly in the mines of Sombrerete, Madroño, Ramos, Zacatecas, Hapujaha, and Sierra de Penos. Throughout Mexico, the ore, though infinitely more abundant, is much poorer than in Europe. The average proportion of silver obtained from the common ore is stated at from 0.0018 to 0.0025; in other words, sixteen hun-

dred ounces of ore contain only from three to four ounces of silver. "The great mass of Mexican ore is so poor," says Garces, in his work on Amalgamation, "that the three millions of marcs of silver which the kingdom yields in good years are extracted from ten millions of quintals of ore, partly by heat, and partly by amalgamation." Indeed, from the vast quantity of silver which Mexico had for centuries poured into the circulation of Europe (sometimes amounting, previously to the revolution of 1810, to between four and five millions sterling annually), the most extravagant notions were at one time entertained respecting the riches of the Mexican mines; and even the best-informed and the most scientific of travellers, Baron Humboldt, confesses that he had been misled by this erroneous opinion, and was surprised to find that the silver ores of Mexico were, as already stated, even poorer than those of Europe, and that the mean produce of the whole mass extracted from the mines was only about one part of metal in four hundred of ore, or about *one quarter per cent.*; a proportion which probably does not differ much from that which is obtained at the present time.

Of the whole mass of the Mexican ores, a small part only, not perhaps above one fifth, is sufficiently rich in metal to render it adapted to the process of smelting; and the remainder is therefore submitted to that of amalgamation, a method which is costly, from the loss both of mercury and of the precious metals which attends it. Much has been done by the English mining companies to lessen this double evil; but a great deal still remains to be effected, and the high price of quicksilver renders any further amelioration of the process a matter of the first importance to all parties concerned in the working of the Mexican mines.

This process, as actually performed, has been described by Gamboa in his *Commentaries on the Mining Ordinances of Spain*; but, from the complicated nature of the operation itself, the obscurity of the technical terms employed, and the difficulty of distinguishing the various changes, chemical and mechanical, which are effected, a description in which the whole subject is as much as possible simplified, and these changes traced in succession as they occur, may not be unacceptable or uninteresting to the reader. The account which follows is more particularly applicable to the process as performed at the extensive hacienda of Sauce-da, belonging to the Bolanos Company, because of it very minute information has been received; but it will nevertheless be found to correspond in almost every respect with the general practice pursued in the various mining districts of Mexico.

Processes at the Mine.

Dressing.—The ores generally consisting of native silver, sulphuret of silver, muriate of silver, argentiferous pyrites, &c. disseminated throughout the vein-stone in a state of minute subdivision, are broken into small pieces with hammers, and partially separated from the matrix.

Processes at the Hacienda.

Preparatory Operations.—The ore first undergoes the process of dry-stamping by the *molinos*, which converts it into a coarse powder called *granza*. The *granza* then undergoes the process of wet-grinding by the *tahonas*, which converts it into a very fine mud or slime called *lama*.

Amalgamation.—The *lama* is first arranged in *tortas*, or flat circular heaps, in the *patio*, or paved court of the hacienda, and well mixed with *saltierra*, or impure muriate

Mines.

¹ The mining districts of the north of Mexico are, in the state of Durango, Guarisamey, San Dimas, Gavilanes, Tayoltita, Canelas, Sianori, Bacis, Tamasula, Ventanas, and San Andres, in the Sierra Madre, and Cuencame (near the river Nazas), Yerva Buena, Mapimi, Indee, El Oro, and Guanasevi, east of the Sierra Madre; in the state of Chihuahua, El Parral, Santa Eulalia, Santa Rosa de Cosiquiriachic, El Pilar, Batopilillas, Rosario, El Potrero, and Milpillas; and in the state of Sonora and Senaloa, Mulatos, Cosala, Alamos, Arispe, and El Rosario.

Mines. of soda (common salt). No chemical change whatever is effected during these processes.

Processes.—Pulverized calcined *magistral*, that is, sulphate of copper and iron, is now added to the *torta*, and by the *repaso* process which follows is thoroughly mixed up with it. Chemical action then commences, and heat is given out.

Chemical Changes.—By the action of the air and moisture the *magistral* is decomposed, and its sulphuric acid set free. The sulphuric acid, thus liberated, rapidly combines with the water contained in the moist *lama*, and great heat is thus evolved, which favours the decomposition of the ores, and the subsequent oxidation of the metal. The sulphuric acid, thus liberated from the *magistral*, having a strong affinity for soda, decomposes the *saltierra*, setting free its muriatic acid, and forming with its base sulphate of soda, or Glauber salt. Owing to its strong affinity for silver, the muriatic acid liberated from the *saltierra* combines with the silver of the ores, and forms muriate or chloride of silver, whilst the portion in excess unites with the copper and iron of the *magistral*, forming muriates of copper and of iron.

Processes.—*Calx* or lime is used, when necessary, to cool the mixture. *Azogue*, or quicksilver, is now applied, by sprinkling it through pieces of coarse cloth, so that it falls in small drops like rain. It is then thoroughly incorporated with the mass, thus forming amalgam. When the first portion of quicksilver is supposed to have been quite taken up, a second supply is added, called *el cebo*. Finally, a third quantity of quicksilver is added, called *el bano*. During these operations the *torta* is thoroughly mixed together by the *repaso*, and other processes. The *torta* or mass of impure amalgam is then washed in the *lavadero*, being thoroughly stirred up in a cistern of water, by which process the earthy impurities are kept in a state of suspension, and finally carried away by the refuse water, which flows off at the top.

Chemical Changes.—The lime appears to act by combining with any portion of the sulphuric acid which may be in excess, and thus forming sulphate of lime or gypsum. The superabundant portion of sulphuric acid being thus taken up, the evolution of heat by its absorption of water is prevented, and the *torta* consequently cools. The mercury, owing to its strong affinity for silver, readily combines with it, forming an amalgam, the muriate appearing to have been previously decomposed by the iron of the *magistral*. Owing to the necessarily imperfect contact of the minute particles of the two metals, the formation of the amalgam is very gradual; hence the mercury is added at intervals, so as to take up the remaining particles of sil-

ver, to insure which it is always greatly in excess. During the washing in the *lavadero*, the muriates of copper and iron, and the sulphates of soda and lime, being all soluble salts, are dissolved in water, and carried off. The amalgam in the mean time settles at the bottom of the *lavadero*.

Processes.—The amalgam, by a further washing in a tub at the *azoguera*, is freed from any earthy impurities which may yet remain. It is then placed in a canvass bag, which is suspended over a vat, and the uncombined quicksilver, owing to its weight, filters through. The pure amalgam, now termed *pella de plata*, is then moulded into wedge-shaped masses, called *marquetas*. In this form it is taken to the *quemadero*, and built up into a cylindrical pile, with a hole down the centre. The pile of amalgam, or *pina de plata*, is then placed on a copper stand, the above aperture opening a communication with the reservoir of cold water below. A large inverted crucible, called the *capellina*, is then placed over the *pina de plata*, and luted at the bottom. No chemical change is effected during these processes. A charcoal fire is then kindled around the *capellina*, the heat of which volatilizes the mercury of the amalgam. The vapour, having no other outlet, passes down the aperture in the middle of the *pina de plata*, and thence through a pipe into a cistern of cold water, where it is immediately condensed.

Chemical Changes.—Volatilization and subsequent condensation of the mercury.

Process.—When the process of distillation has continued for a sufficient time, the *capellina* is removed, and the crude silver, now forming a solid mass, is broken up into the original *marquetas*. The *marquetas* are then placed in a test with charcoal, and melted down by the action of a blast. By this process the silver is freed from any slight impurities which yet remain attached to it.

Chemical Change.—Silver refined by fusion.

Process.—Whilst in a state of fusion, the silver, now pure, is poured into a mould, and cast into bars, in which form it is sent to the mint for coinage. The general weight of the bars is about 135 Spanish marcs, or 82 lbs. troy, and the value about L.270, although depending, of course, on the fineness of the metal, and sometimes regulated by its containing a ley of gold.¹

Having thus explained the process of amalgamation, we shall now proceed to lay before our readers the most recent information which has been obtained respecting the produce of the Mexican mines. The following statement of the coinage in all the mints of the Mexican republic, during the year ending the 31st of December 1834, is contained in a communication by Consul-General O'Gorman, addressed to the Duke of Wellington.²

MINTS.	GOLD.	SILVER.	TOTAL.
	Value in Dollars.	Dollars.	Dollars.
Mexico.....	14,656	938,055	952,711
Guanaxuato.....	196,448	2,506,500	2,702,948
Zacatecas.....	...	5,526,600	5,526,600
San Luis Potosi.....	...	927,800	927,800
Guadalaxara.....	783	714,439	715,222
Durango.....	...	1,215,530	1,215,530
Total, dollars.....	211,887	11,828,924	12,040,811
At 48d. per dollar.....	L.42,377	L.2,365,785	L.2,408,162

¹ See Mining Review, No. VIII. p. 249, et seq.

² See Parliamentary Paper, entitled Comparative Statement of the Value Sterling of Gold and Silver raised in each of the Mining Countries of America and Russia, p. 6.

Mines.

It appears, however, that the export of the precious metals from Mexico in 1834 amounted to upwards of twenty-one millions, to which must be added the legal and clandestine exports by Matamoros, supposed to be about two millions, and the smuggled treasure from Vera Cruz and the smaller ports, estimated at one million and a half; so that about twenty-five millions of dollars in gold and silver, equal to L.5,000,000 sterling, were, in 1834, shipped to foreign countries, although the coinage of all the mints of the republic during that year was only 12,040,811 dollars, as shown by the above return, or L.2,400,000. A large proportion of this export was for the United States. "The produce of the Mexican mines," says Mr O'Gorman, "has evidently increased to a great extent, notwithstanding the exorbitantly high price of quicksilver, which has prevented the reduction of ores of low quality for the last two years; and the riches lately discovered in the mines of Fresnillo, and again at Zacatecas, promise a still greater augmentation of silver."

V.—SOUTH AMERICAN MINES.

Under this head it will not be necessary for us to enter into any lengthened details, because ample information on the subject of the mines of South America will be found in the various articles of this work especially devoted to the description of the different countries, or states, into which that great continent is now divided, particularly in the accounts given of Bolivia, Brazil, Buenos Ayres, Chile, Colombia, Peru, &c. to which accordingly the reader is referred.

There are few regions of the earth so remarkable for their mineral riches as the vast primitive chain of mountains called the Cordilleras, throughout which nature has distributed ores of the precious metals in greater abundance than in almost any other part of the world; although these are for the most part placed at an elevation which renders the working of them equally difficult and expensive. The most important mines are those of silver; but gold, quicksilver, copper, and lead are also extracted, some of them in very considerable quantities.

In Chile, especially in the province of Coquimbo, there are several mines of silver, and some important ones of copper. The Chileno mines are mostly situated in the interior of a hilly country of difficult access, to which the conveyance of fuel and materials is enormously expensive, and whence the transport of the produce to the places of embarkation is attended with much difficulty. The Chileno miners are described as very expert in following the course of a vein, though entirely ignorant of any thing like science, and even unable to explain the rules by which they are guided in pursuing their operations. The various processes followed in the reduction of the ores are also rude and simple; but being extremely economical, they are perhaps better adapted to the circumstances of the country than those which are employed in less difficult and more accessible regions. The greater proportion of the gold found in Chile is obtained from the auriferous sulphuret of iron, or gold pyrites, which is generally met with in high and lofty ridges, such as those of Illapel and Petorca. Some portion, however, is obtained from veins of rock, where very small grains of gold are disseminated in syenite, so minute as not to be visible to the naked eye, or from an ochreous decomposing syenite, distributed in veins, throughout which native gold is disseminated in thin flakes. Silver is found principally in limestone, or calcareous syenite; and it also occurs in beds of quartz, amongst which it is disseminated in the metallic state. But towards Copiapo it is generally found

in lead ores, principally argentiferous galenas; and towards the south it occurs mineralized with sulphur. Copper is most frequently found in the state of sulphuret called bronze, but sometimes in that of carbonate, or sulphuret and carbonate intermixed.¹

The richness of the silver mines of Potosi, now included in the territory of Buenos Ayres, may be judged of from the fact, that since the period of their discovery in the year 1545, upwards of 1300 millions of dollars have been coined there. These mines are situated in an insulated mountain, about eighteen miles in circumference, which rises to an immense height, in the form of a sugar-loaf or cone; it is about an hundred leagues distant from the South Sea, near the sources of the river La Plata, is chiefly composed of a yellow, firm, argillaceous slate, and is full of veins which traverse the mountain in all directions, and are filled with ferruginous quartz, which constitutes the matrix of the silver ores. These consist principally of native silver and vitreous silver ore, the latter of which, on the first discovery of the mine, yielded about half its weight of pure silver; but the produce is much less now than formerly, all the richer veins having been wrought out and exhausted. Copper, lead, and tin, are also found in Buenos Ayres, the last occurring in beds of sand or clay, from which it is obtained by washing. On the opposite chain, in a level district, are the silver mines of Guantajaya, famous for the large masses of solid silver which they formerly yielded, and one of which weighed about 800 lbs.

In Peru there are forty districts particularly famous for their gold and silver mines. Gold is chiefly found in the provinces of Guailas and Pataz, and silver in the districts of Guantajaya, Pasco, and Chota. The celebrated mines of Pasco, which, some thirty years ago, produced considerably more than two millions of dollars annually, had, like most of those of South America, been very negligently managed until, in 1816, miners from Cornwall began to work them by means of steam-engines. These mines are properly in the ridge of Yauricocha, and are situated at the great height of 13,500 feet above the level of the sea. The distance of the village of Pasco from Lima is about fifty-eight leagues. The only persons capable of being employed at so great an elevation, where the barometer is always below nineteen inches, are the Indians of the country, who, being bred upon high table-lands, can alone respire without inconvenience the attenuated atmosphere of so lofty a region. The riches of the metalliferous bed of Yauricocha are at no great depth below the surface, the greater proportion of the pits being somewhat less than 100 feet, and none of them exceeding 400 feet in depth. The length of this bed is about 16,000 feet, its breadth 7200 feet, and its thickness somewhat less than 100 feet. The number of mines does not exceed an hundred. The mineral bed consists of a porous ironstone, throughout which fine silver is disseminated; but patches of a friable white argillaceous earth about ten inches in thickness are sometimes met with in the midst of the large bed, and are often so rich as to yield from 200 to 1000 marcs per caxon. The consequence has been, that many miners, instead of following the bed regularly, have perforated it at random in search of these very uncertain riches, and, from carelessness, have endangered the existence of the whole mine. In fact, it is these perforations which are now denominated mines. The mines of the province of Chota now furnish above 40,000 lbs. troy of silver annually. The quicksilver mine of Guancavelica in Peru is the only one of this kind in the New World. It is about fifty leagues to the eastward of Lima, being situated near the summit of one of the Cordilleras. This mine, which, for a period of two centuries, afforded annually from 7000 to 8000 quintals of

Mines.

¹ Miers' Travels in Chile and La Plata, vol. ii. chap. 22 and 23.

Mines. mercury is now nearly exhausted. The cinnabar of Guancavelica is disseminated in a sandstone similar to that of Almaden in Spain, being distributed in an immense accumulated mass, without the form of bed or vein; but the ore has become so poor that fifty quintals do not now yield more than six or eight pounds of mercury.

In the province of Guantajaya, there are mines of rock or fossil salt. To the north of the province of Chota, the Cordilleras are by no means so rich in metals. In New Granada, however, there are several silver mines; at Aroa, in Caraccas, there is a copper mine which yields from 1400 to 1600 cwt. of metal annually; and at Santa Fe de Bogota

rock-salt and pit-coal are found. For an account of the gold and diamond mines or districts of Brazil, the reader is referred to the article under that head.

It now only remains to endeavour, by means of the tabular returns obtained from the British consular agents in South America, to exhibit a view of the actual produce of the gold and silver mines of that country. The following is an account of the gold, silver, and copper, raised from the mines in the province of Coquimbo, in Chile, distinguishing the different ports and mining districts from which the metals have been exported and remitted by land during the year ending the 31st December 1831:—

PORTS and MINING DISTRICTS.	Shipped to Foreign Countries, and in Foreign Bottoms.			Shipped to Valparaiso, Concepcion, Chile, and Ports of Peru, in Chilean Bottoms.			Remitted by Land to the Capital, Santiago, and to the Port of Valparaiso.			Total.		
	Gold.	Silver.	Copper.	Gold.	Silver.	Copper.	Gold.	Silver.	Copper.	Gold.	Silver.	Copper.
	Lbs.	Marc.	Quintals.	Lbs.	Marc.	Quintals.	Lbs.	Marc.	Quintals.	Lbs.	Marc.	Quintals.
Coquimbo.....	...	42,572½	23,432	40½	11,368	39	...	31,858	3	40½	85,798½	23,474
Huasco.....	...	...	13,420½	...	3,232½	7,594	...	8,934	...	...	12,166½	21,014½
Copiapo.....	...	1,686	2,707½	...	62,224½	2,702	...	8,161½	...	...	72,072	5,409½
Districts of Illapel and Combarbala.....	...	...	...	...	...	...	...	...	7,000	...	...	7,000
Total.....		44,258½	39,560	40½	76,825	10,335		48,953½	7,003	40½	170,037	56,898

The total value of the different quantities above stated, estimated in the currency of Chile, amounted to 2,379,539 dollars. The quantity of gold actually raised from the mines, however, is said to be much greater than that here stated; but no accurate account of the quantity extracted could be procured, owing to the circumstance of the article being chiefly exported in a clandestine manner, in order to avoid the duties, which are about four per cent. *ad valorem*. For this reason, any returns that can be obtained are comparatively of but little avail, as far as gold is concerned.

The following return of the marcs of gold coined at the mints of Lima and Cuzco between the years 1820 and 1833, is copied from the parliamentary paper to which we have already referred:—

Years.	Amount of Coinage at both Mints.					
	Marc.	Dollars.	Rs.	£	s.	d.
1820	3,690 1	533,223	0½	106,644	12	3
1821	1,957 4	282,853	6	56,571	15	0
1822	1,086 7	157,053	3½	31,410	14	1
1823	179 4	25,937	6	5,185	11	0
1824 } 1825 }	No coinage.	No coinage.	No coinage.			
1826	2,781 5	401,944	6½	80,388	19	3
1827	730 6	105,593	3	21,118	13	6
1828	622 3	89,933	1½	17,986	12	9
1829	903 4	130,555	6	26,111	3	0
1830	1,256 7	181,618	3½	36,323	13	9
1831	636 7	92,028	3½	18,405	13	9
1832	517 7	74,832	7½	14,966	11	9
1833	438 0	63,291	0	12,658	4	0
Totals,	14,801 7	2,138,870	7½	427,774	3	9

We shall next exhibit, from the same Comparative Statement, a return of the amount and value of silver coined at the mint of Lima between the 1st of January 1820 and the 31st of December 1833:—

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Years.		At 8½ Dollars per Marc.	At 5 Dollars per Pound Sterling.
	Marc.	Dollars. Rs.	£ s. d.
1820	469,808	3,758,464 0	751,692 16 0
1821	157,957	1,342,634 4	268,526 16 0
1822	193,200	1,642,200 0	328,440 0 0
1823	60,000	510,000 0	102,000 0 0
1824	...	...	...
1825	67,638	574,923 0	114,984 12 0
1826	217,050	1,844,925 0	368,985 0 0
1827	318,000	2,703,000 0	540,600 0 0
1828	264,000	2,244,000 0	448,800 0 0
1829	130,150	1,106,275 0	221,255 0 0
1830	193,500	1,644,750 0	328,950 0 0
1831	217,909	1,850,226 4	370,445 6 0
1832	312,700	2,657,950 0	531,590 0 0
1833	301,600	2,563,600 0	512,720 0 0
Total,	2,903,512	24,444,948 0	4,888,989 10 0

The number of marcs of silver coined at the mint of Cuzco between the years 1824 and 1832 was as follows, viz.

Years.		At 8½ Dollars per Marc.	At 5 Dollars per Pound Sterling.
	Marc.	Dollars. Rs.	£ s. d.
1824	37,300	317,050 0	63,410 0 0
1825	28,061	238,518 4	47,703 14 0
1826	57,989	492,906 4	98,581 6 0
1827	30,856	262,276 0	52,455 4 0
1828	37,703	320,475 4	64,095 2 0
1829	35,278	299,863 0	59,972 0 0
1830	42,835	364,097 4	72,819 10 0
1831	62,790	533,715 0	106,743 0 0
1832	64,876	551,446 0	110,289 4 0
Totals,	397,688	3,380,348 0	676,069 0 0

From this and the preceding return taken together, it therefore appears that the

	Marc.	Dollars.	£	s.	d.
Total coinage of silver at the mint of Lima, in 13 years from 1820 to 1833, not including 1824, amounted to.....	2,903,513	24,444,938	4,882,924	12	0
Coinage of silver at the mint of Cuzco, from 1824 to 1832 (the return for 1833 not having been received), was.....	397,688	3,380,348	676,069	0	0
Amount of coinage of silver at both mints....	3,301,201	27,825,286	5,558,993	12	0

The next return which we shall give exhibits the number of marcs of silver of eight ounces reduced to bars at the different smelting houses of the republic of Peru therein specified, during the years from 1819 to 1833 both inclusive, as far as the same could be procured by the consul-general of Great Britain, in that country.

Years.	Lima.	Trujillo.	Pasco.	Ayacucho.	Puno.	Arequipa.	Tanca.	Total in Marcs.	In Dollars, at 84 Dollars per Marc.	In Pounds Sterling, at 5 Doll. per Pound.
1819	96,594 0	26,998 0	190,427 0	5,157 2	25,172 7	27,910 1	5,575 5	422,834 7	3,488,387 5 ⁶ / ₈	697,677 15 0
1820	50,819 0	24,403 0	283,906 0	2,639 0	24,898 5	37,405 4	6,004 2	430,075 3	3,548,121 6 ³ / ₄	709,624 7 0
1821	74,481 3	10,462 7	...	1,022 0	16,667 5	10,486 0	5,661 5	118,781 4	979,947 3	195,989 9 6
1822	64,470 3	17,983 2	...	2,213 1	14,989 1	2,040 0	2,785 1	104,181 0	859,593 2	171,918 13 0
1823	...	17,237 6	...	2,148 2	14,960 7	413 7	...	34,760 6	186,776 1 ¹ / ₂	37,355 4 9
1824	...	43,263 6	...	8,341 7	11,629 7	3,203 7	2,028 1	68,467 4	564,856 7	112,971 7 6
1825	21,010 3	4,956 1	56,971 0	...	8,400 0	15,237 2	3,493 0	110,068 4	908,065 1	181,613 4 6
1826	23,361 3	16,108 3	163,852 0	3,170 1	16,658 0	28,368 3	805 6	252,324 0	2,081,673 0	516,334 12 0
1827	15,607 3 ¹ / ₂	11,997 3	221,707 0	2,922 2	21,999 3	11,671 4	119 5	286,024 5 ¹ / ₂	2,359,703 2 ⁷ / ₈	571,940 13 1
1828	7,400 3	5,395 5 ¹ / ₂	201,330 0	1,841 3	22,931 4	7,370 3	4,720 7	250,540 1 ¹ / ₂	2,066,956 2	513,391 5 0
1829	6,453 3	1,760 4	82,031 0	5,634 4	27,327 7	12,973 3	2,270 0	138,900 5	1,145,930 1 ¹ / ₂	229,186 0 6
1830	33,145 7	23,550 5	95,265 0	12,336 0	30,758 6	18,422 5	212 5	213,691 4	1,762,954 7	352,590 19 6
1831	34,262 0	7,109 5	135,134 4	9,267 2	38,417 0	14,472 5	...	238,663 0	1,968,968 6	393,793 15 0
1832	34,975 1	11,721 1	219,378 1	8,776 0	42,130 4	2,851 0	...	319,831 7	2,638,612 7 ⁶ / ₈	527,722 12 0
1833	27,974 2	8,530 0	257,669 6	5,730 4	2,986 0	7,684 0	...	310,574 4	2,562,242 1	512,460 8 6

The following table shows the number of marcs of silver smelted at the different smelting houses of Peru during the three quinquennial periods from the beginning of 1819 to the end of 1833, and likewise the value of the silver thus smelted in dollars and pounds, for each separate period of five years:—

Quinquenniums.	Marc.	Dollars.	Rs.	£	s.	d.
1819 to 1823.....	1,110,663 4	9,162,726 3		1,832,545	5	6
1824 to 1828.....	967,424 6 ³ / ₄	7,981,254 7 ⁵ / ₈		1,596,250	19	6
1829 to 1833.....	1,221,661 4	10,078,707 3		2,015,741	9	6
Total for the 15 years,	3,299,719 6 ³ / ₄	27,222,688 5 ⁵ / ₈		5,444,537	14	6

From a return of the silver coined in Peru between the 1st of January and the 31st of December 1834, it appears that the total amount of the coinage in 1834 exceeded the total amount of the coinage in 1833 by 18,586 marcs, which

are equal to 121,764 dollars, or L.24,352. 8s.; thus showing that the working of the silver mines in that country is at length proceeding with increased spirit, activity, and success. (A.)

MINES, MILITARY, denote subterranean galleries or passages excavated under the walks or ramparts of fortifications, and intended to be blown up by gunpowder.

The gallery or passage of a mine is commonly about four feet square, and at the end of this is the chamber or *fourneau* of the mine, which is a cavity of about five feet in width, the same in length, and about six feet in height; and here the gunpowder is stowed. The saucisson of the mine is the train, for which there is always a small aperture left.

Two ounces of powder have been found, by experiment, capable of raising two cubic feet of earth; consequently 200 ounces, that is, twelve pounds eight ounces, will raise 200 cubic feet, or sixteen feet less than a cubic toise; because 200 ounces, joined together, have proportionally a greater force than two ounces, from being an united force.

All the turnings which a miner employs to carry on his mines, and through which he conducts the saucisson, should be well filled with earth and dung; and the masonry, in proportion to the earth to be blown up, should be as three to two. The entrance of the chamber or *fourneau* of the

mine ought to be firmly shut with thick planks, in the form of a St Andrew's cross, so that the enclosure be made secure, and the void spaces filled up with dung or tempered earth. If a gallery be formed below or on the side of the chamber, it must absolutely be filled up with the strongest masonry, half as long again as the height of the earth; for this gallery will not only burst, but likewise obstruct the effect of the mine. The powder should always be kept in sacks, which must be opened when the mine is charged, and some of the powder strewed about. The greater is the quantity of earth to be raised, the more decided will be the effect of the mine, supposing it to have the due proportion of powder. Powder has the same effect upon masonry as upon earth; that is, it will proportionally raise either with the same velocity.

The branches which are carried into the solidity of walls seldom exceed three feet in depth, and two feet six inches in width, or thereby. This species of mine, when properly formed, is calculated to blow up the strongest walls.

The weight of a cubic foot of powder should be about 80 lb.; one foot one inch cube should weigh 100 lb., and

Mines, Military. one foot two inches and $\frac{1}{2}$ ths, 150 lb. : on the other hand, 200 lb. of powder will be one foot five inches cube ; but there is a diversity in this, according to the quantity of salt-petre contained in the gunpowder.

If, when the mines are formed, water be found at the bottom of the chamber, planks are laid there, upon which the powder is placed, either in sacks or barrels of 100 lb. each. The saucisson must have a clear passage to the powder, and should be laid in an *auget* or wooden trough, through all the branches. When the powder is placed in the chamber, the planks are laid to cover it, and others again across these, then one is placed across the top of the chamber, which is shaped for that purpose ; and between it and those which cover the powder, props are placed, which shore it up, some inclining towards the outside, and others to the inside of the wall, all the void spaces being filled up with earth, dung, bricks, and rough stones. Afterwards planks are placed at the entrance of the chamber, with one across the top, upon which are buttressed three strong props, the other ends of which are likewise propped against another plank situated on the side of the earth in the branch ; and these props being well fixed between the planks with wedges, the branch should then be filled up to its entrance with the before-mentioned materials. The saucissons which pass through the side branches must be of exactly the same length with that in the middle, to which they are joined. The part which reaches beyond the entrance of the mine is that which conveys the fire to the other three ; and if the saucissons be of equal length, the mines will spring together.

From a great number of experiments, it appears that the force of a mine is always towards the weakest side, so that the disposition of the chamber of a mine does not at all contribute to determine this effect ; that the quantity of powder must be greater or less in proportion to the greater or less weight of the bodies to be raised, and to their greater or less cohesion ; that the entonnoir of a mine,¹ if rightly charged, is a cone, the diameter of whose base is double the height taken from the centre of the mine ; that when the mine has been overcharged, its entonnoir is nearly cylindrical, the diameter of the upper extreme not much exceeding that of the chamber ; and that, besides the shock of the powder against the bodies it takes up, it likewise crushes all the earth which borders upon it, both underneath and sidewise.

To charge a mine so as to produce the most advantageous effect, the weight of the matter to be carried must be known ; that is, the solidity of a cone whose base is double the height of the earth over the centre of the mine. Thus, having found the solidity of the cone in cubic fathoms, multiply the number of fathoms by the number of pounds of powder necessary for raising the matter it contains ; and if the cone contain matters of different weights, take a mean weight between them all, due regard being always had to their degree of cohesion. As to the disposition of mines, there is but one general rule, which is, that the side towards which the miner would determine the effect be the weakest ; but this varies according to occasions and circumstances.

The calculation of mines is generally built upon the hypothesis, that the entonnoir of a mine is the frustum of an inverted cone, the altitude of which is equal to the radius of the excavation of the mine, and the diameter of the whole lesser base is equal to the line of least resistance ; and although these suppositions are not quite exact, yet the calculations of mines deduced from them have proved successful in practice ; for which reason this principle should be followed until a better and more simple be found out. M. de Vallière found that the entonnoir of a mine was a para-

boloid, which is a solid generated by the rotation of a semi-parabola about its axis ; but as the difference between these two solids is very insignificant in practice, that of the frustum of a cone may be used.

The mines of a fortress are denominated *counter-mines*, the gallery of which runs under the covered way, along the outer margin of the fosse. From this, ramifications (*rameaux*) extend under the glacis, whence little passages are formed on both sides, so as to afford means for listening and discovering the subterranean proceedings of the enemy. Galleries made within a fortification, before a place is attacked, and from which branches are carried in different directions, are generally about four feet in width and about five in height. The earth is supported from falling in by arches and walls, as these galleries are intended to remain for a considerable time ; but when mines are to be used as soon as formed, the galleries are only three feet or three feet and a half in width, and five feet in height, and the earth is temporarily supported by wooden frames or props.

A word or two now respecting the *globe de compression*. Suppose a large globe of earth, homogeneous in all its parts, with a certain quantity of powder lodged in its centre, so as to produce a proper effect without bursting the globe ; it is evident that, by the ignition of the powder, the explosion will act equally all round, and the particles of earth, being porous, will compress each other in proportion as the expansive force increases the dimensions of the chamber. The particles of earth next to the chamber will communicate a portion of their motion to those adjoining, and the latter to those immediately beyond them ; and this communication will continue in a decreasing proportion, until the whole force of the explosion be spent ; but beyond that limit the particles of earth will remain in the same state as before. Thus the particles of earth which have been acted upon by the force of the explosion will form a globe, and to a certain extent drive all before them. This is the *globe de compression* invented by Belidor. Its object is, without any explosion perceptible at the surface, to shake the ground, and to destroy the hostile mines in the immediate neighbourhood.

Fougasses are a sort of small mines constructed before the weakest parts of a fortification, as the salient angles and the faces when not defended by a cross fire. *Treble mines* are mines with two chambers only. *T-mines*, so called from their resemblance to the letter T, are double mines having four lodgments. Double T-mines have eight lodgments and four doors, whilst triple T-mines have twelve lodgments and six doors. Double treble mines have four lodgments and eight doors ; triple treble mines have six lodgments and twelve doors.

Subterranean warfare has many peculiarities, and requires a rare union of skill, and courage, and perseverance. Sappers and miners are usually armed with pistols and cutlasses for their defence, when there is a chance of their meeting a hostile counter-mine ; and if a combat ensue, the dead and the wounded are passed backwards from the most advanced workmen to those behind, until the mine is cleared. Balls made of all kinds of substances which produce an offensive stench when ignited, are also lighted, in order to stop the enemy, whenever the mine permits the party who set fire to the ball to effect an easy retreat from the mine. Sometimes mines are excavated in the field, for the purpose of blowing up such of the enemy as can be allured to the spot. In these cases, a small body of men is commonly placed immediately above the mine, to induce the enemy to attack with a superior force ; if the stratagem succeed, the mine is instantly sprung (*on fait jouer la mine*), and, from the very nature of the operation, both parties are sometimes sacrificed.

¹ That is, the cavity, aperture, or hole which remains after the explosion.

Mingrelia
||
Miniature
Painting.

MINGRELIA, a large country of Asia, extending about 140 miles in length along the Black Sea, which bounds it on the west, and stretching into the interior about forty or fifty miles. It is situated on the southern side of the Caucasus, between the Caspian and the Black Sea, and is bounded on the north by Georgia, on the east by Immeritia, and on the south by the river Phasis. The country, though it possesses great natural capabilities, has greatly declined, and is now sunk in poverty and barbarism. The soil, near the Black Sea more particularly, is soft and moist, and neither wheat nor barley can be raised to any extent. It is chiefly on a small grain resembling coriander seed that the people subsist. Vines are plentiful, as is also honey; and the climate is favourable for silk. There are, however, no manufactures of any great value in the country; they consist chiefly of coarse taffeties, and an indifferent sort of handkerchiefs. A great trade is carried on in slaves, of which the number exported is about 12,000. The inhabitants are all of turbulent and predatory habits; fishing, war, and plunder, are the principal occupations of the chiefs. The females are remarkably handsome in their persons. This extensive tract of country, which long fluctuated in its obedience between the Russians and the Turks, is now under the dominion of the former. The Phasis, and its tributaries the Teghuri and Arascha, are the principal rivers. It has few towns worthy of the name. The largest is called Zalikara; Rugh and Egers are well fortified; and Rhœzia has an extensive trade. The country is well watered, and covered with extensive forests of the finest trees. The province, according to Reineggs, contains four millions of inhabitants.

MINHO, a great river in Spain, which, taking its rise in Galicia, divides that province from Portugal, and falls into the Atlantic at Caminha.

MINIATURE, in a general sense, signifies representation in a small compass, or diminished form.

MINIATURE PAINTING, a delicate kind of painting, consisting of little points or dots, usually done on vellum, ivory, or paper, with very thin, simple water colours. The word comes from the Latin *minium*, red lead, that being a colour much used in this kind of painting. The French frequently call it *mignature*, from *mignon*, fine, pretty, on account of its smallness and delicacy; and it may be ultimately derived from the Greek word *μικρος*, small.

Miniature is distinguished from other kinds of painting by the smallness and delicacy of its figures, and the faintness of the colouring.

OF DRAWING AND DESIGNING.—To succeed in this art, a man should be perfectly skilled in the art of designing or drawing; but as most people who affect the one know little or nothing of the other, and would have the pleasure of painting without giving themselves the trouble of learning to design, which is indeed an art that is not acquired without a great deal of time and continual application, inventions have been found out to supply its place, and by means of which a man may design or draw without knowing how to do either.

The first is chalking; that is, if you have a mind to do a print or design in miniature, the back of it, on another paper, must be blackened with small coal, and then rubbed very hard with the finger wrapped in a linen cloth; afterwards the cloth must be lightly drawn over the side so blackened, that no black grains may remain upon it to soil the vellum you would paint upon; and the print or draught must be fastened upon the vellum with four pins, to keep it from shifting. And if it be another paper that is blackened, it must be put between the vellum and the print or draught, with the blackened side upon the vellum; then, with a blunted pin or needle, you must pass over the principal lines or strokes of the print or draught,

the contours, the plaits of the drapery, and every thing else that must be distinguished, pressing so hard that the strokes may be fairly marked upon the vellum underneath.

Copying by squares is another convenient method for such as are but little skilled in the art of designing, and would copy pictures or other things that cannot be chalked. The method may be shortly described. The piece must be divided into many equal parts by little squares, marked out with charcoal, if the piece be clear and whitish, and the black can be fairly seen upon it; or with white chalk, if it be too brown and dusky. After which, as many squares of equal dimensions must be made on white paper, upon which the piece must be designed; because, if this be done immediately upon vellum (as one is apt to miscarry in the first attempt), the vellum may be soiled with false touches. But when it is neatly done upon paper, it must be chalked upon the vellum in the manner before described. When the original and the paper are thus ordered, observe what is in each square of the piece to be designed, as a head, an arm, a hand, and so forth; and place it in the corresponding part of the paper. And thus finding where to place all the parts of the piece, you have nothing to do but to form them well, and to join them together. By this method you may reduce or enlarge a piece to whatever compass you please, making the squares of your paper greater or less than those of the original; but they must always be of an equal number.

To copy a picture or other thing in the same size and proportion, another method is, to make use of varnished paper, or of the skin of a hog's bladder, very transparent, such as is to be had at the gold-beater's. Talc or isinglass will likewise do as well. Lay any one of those things upon your piece; through it you will see all the strokes and touches, which are to be drawn upon it with a crayon or pencil. Then take it off; and fastening it under paper or vellum, set up both against the light, in the manner of a window; and with a crayon, or a silver needle, mark out upon the paper or vellum you have put uppermost, all the lines and touches you shall see drawn upon the varnished paper, bladder, talc, or isinglass, you have made use of, and which will plainly appear through this window.

After this manner, making use of the window, or of glass exposed to the light, you may copy all sorts of prints, designs, and other pieces, on paper or vellum, laying and fastening them under the paper or vellum upon which you would draw them; and it is a very good and a very easy contrivance for doing pieces of the same size and proportion.

If you have a mind to make pieces look another way, there is nothing to be done but to turn them; laying the printed or drawn side upon the glass, fastening the paper or vellum upon the back of it, and remembering to let your lights fall on the left side.

A good method likewise to take a true copy of a picture in oil, is to give a touch of the pencil upon all the principal strokes, with lake tempered with oil, and to clap upon the whole a paper of the same size; then passing the hand over it, the touches of the lake will stick and leave the design of your piece expressed upon the paper, which may be chalked like other things. But you must remember to take off with a crumb of bread what remains of the lake upon the picture before it be dry. You must likewise make use of pounce, made of powdered charcoal put in a linen rag; with this the piece you would copy must be rubbed, after you have pricked all the principal strokes or touches, and fastened white paper or vellum underneath.

When the piece is marked out upon the vellum, you must pass with a pencil of very clear carmine over all the traces, that they may not be effaced as you work; then

Miniature
Painting.

Miniature Painting. clean your vellum with the crumb of bread, that no black may remain upon it.

The vellum must be pasted upon a plate of brass or wood, of the size you would make your piece, in order to keep it firm and tight. But this pasting must be on the edges of your vellum only, and behind the plate, for which purpose your vellum must exceed your plate above an inch on every side; for the part you paint upon must never be pasted, because it would not only give it an ill look, but you could not take it off if you would. Cut off the little shags and locks of the vellum, and, wetting the fair side with a linen cloth dipped in water, clap the other upon the plate, with a clean paper between them; let as much as hangs over be pasted upon the back of the plate, drawing it equally on all sides, and hard enough to stretch it well.

OF MATERIALS.—As colours taken from earth and other heavy matter are always too coarse, be they ever so well ground, especially for delicate work, because of a certain sand remaining in them, the finest parts may be drawn out by diluting them with the finger in a cup of water. When they are well steeped, let them settle a while; then pour out the clearest, which will be at top, into another vessel. This will be the finest, and must be let dry; and, when it is used, it must be diluted with gum-water.

Some colours are made clearer by fire, as yellow ochre, brown red, ultramarine, and umber; all others are darkened by it. But if you heat these colours with a sharp fire, they will change; the brown-red will become yellow, yellow ochre will become red, and umber will also redden. Ceruss, by fire, takes the colour of citron, and is often called *masticot*. Observe, that yellow ochre heated becomes more tender than it was, and softer than brown-red; likewise brown-red heated becomes softer than fine yellow ochre. Both are very proper. The finest and truest ultramarine, heated upon a red-hot iron, becomes more glittering than before; but it wastes, and is coarser and harder to work with in miniature.

All these colours are diluted in little cups of ivory, made on purpose, or in sea-shells, with water in which gum-arabic and sugar-candy are put. For instance, in a glass of water put a piece of gum as big as a walnut, and half that quantity of sugar-candy. This last hinders the colours from scaling when they are laid on, which they generally do when they want it, or the vellum is greasy. This gum-water must be kept in a neat bottle corked; and you must never take any out of it with a pencil that has colour upon it, but with a quill, or some such thing.

Some of this water is put into the shell with the colour you would temper, and diluted with the finger till it be very fine. If it be too hard, you must let it soften in the shell with the said water before you dilute it. Afterwards let it dry; and do this with every colour, except lily-green, sap-green, and gamboge, which must be tempered with fair water only. But ultramarine, lake, and bistre, are to be more gummed than other colours.

If you make use of sea-shells, you must let them steep two or three days beforehand in water; then cleanse them in boiling-hot water mixed with vinegar, in order to carry off a certain salt, which otherwise sticks to them, and spoils the colours that are put in them.

To know whether colours are sufficiently gummed, you have nothing to do but to give a stroke of the pencil upon your hand when they are diluted, which dries immediately: if they chap and scale, there is too much gum; if they rub out by passing the finger over them, there is too little. It may be seen likewise when the colours are laid on the vellum, by passing the finger over them. If they stick to it like a powder, it is a sign there is not gum enough, and

Miniature Painting. more must be put to the water with which you temper them; but take care you do not put too much, for that makes the colour extremely hard and dry. It may be likewise known by their glueiness and brightness; for the more they are gummed, the darker they paint; and when you have a mind to give a greater strength to a colour than it has of itself, you have nothing to do but to give it a great deal of gum.

The use of good pencils is a great matter. In order to make a good choice, wet them a little; and if the hairs keep close together as you turn them upon the finger, and make but one point, they are good; but if they close not together, but make several points, and some are longer than others, they are good for nothing. When they are too sharp pointed, with only four or five hairs longer than the rest, yet closing altogether, they are, notwithstanding, good; but they must be blunted with a pair of scissors, taking care at the same time you do not clip away too much. It is proper to have two or three sorts of them; the largest for laying the grounds and dead-colouring, and the smallest for finishing.

To work well in miniature, you must do it in a room which has but one window, and fix yourself very near it, with a table and desk almost as high as the window; placing yourself in such a manner that the light may always come in upon the left side, and never forward or upon the right.

When you would lay a colour on all parts equally strong, as for a ground, you must make your mixtures in shells, and put in enough for the thing you design to paint; for if there be not enough, it is a great chance but the colour you afterwards mix is too dark or too light.

OF WORKING.—After having spoke of vellum, pencils, and colours, let us now show how they are to be employed. In the first place, then, when you would paint a piece, be it carnation, drapery, or any thing else, you must begin by dead-colouring; that is to say, by laying your colours on with liberal strokes of the pencil, in the smoothest manner you can, as the painters do in oil, not giving it all the force it is to have for a finishing; in other words, make the lights a little brighter, and the shades less dark, than they ought to be, because in dotting upon them, as you must do after dead-colouring, the colour is always fortified, and would at last be too dark.

There are several ways of dotting, and every painter has his own. Some make their dots perfectly round; others make them a little longish; others hatch by little strokes that cross each other every way, till the work appears as if it had been wrought with dots. This last method is the best, the boldest, and the soonest done; wherefore such as would paint in miniature ought to use it, and to inure themselves from the first to dot in the plump and the soft way; that is to say, where the dots are lost, in a manner, in the ground upon which you work, and only so much appears as is sufficient to make the work seem dotted. The hard and the dry way is quite the reverse, and always to be avoided. This is done by dotting with a colour much darker than your ground, and when the pencil is not moistened enough with the colour, which makes the work seem rough and uneven.

Study likewise carefully to lose and drown your colours one in another, so that it may not appear where they disjoin; and to this end soften or allay your touches with colours that partake of both, in such sort that it may not appear to be your touches which cut and disjoin them. By the word *cut*, we are to understand what manifestly separates and divides, and does not run in and blend itself with the neighbouring colours, which is rarely practised but upon the borders of drapery.

When your pieces are finished, to heighten them a little, give them a fine air; that is to say, give, upon the extre-

Miniature Painting. mity of the lights, small touches with a colour yet lighter, which must be lost and drowned with the rest.

When the colours are dry upon your pallet or in your shells, in order to use them they must first be diluted with water; and when you perceive they want gum, which is seen when they easily rub off the hand or the vellum if you give a touch with them upon either, they must be tempered with gum-water instead of pure water, till they are in condition.

There are several sorts of grounds for pictures and portraits. Some are wholly dark, composed of bistre, umber, and Cologne earth, with a little black and white; others more yellow, in which is mixed a great deal of ochre; others grayer, which partake of indigo. In order to paint a ground, make a wash of the colour or mixture you would have it, or according to that of the picture or portraiture you would copy; that is to say, a very light lay, in which there is hardly any thing but water, in order to soak the vellum. Then pass another lay over that, somewhat thicker, and strike it on very smoothly with large strokes, as quick as you can, not touching twice in the same place before it be dry; because the second stroke carries off what has been laid on at the first, especially when you lean a little too light upon the pencil.

Other dark grounds are likewise made of a colour a little greenish; and these are most in use, and the properest to lay under all sorts of figures and portraits, because they make the carnation or naked parts of a picture appear very fine, are laid on very easily, and there is no occasion to dot them, as one is often obliged to do the others, which are rarely made smooth and even at the first; whereas in these one seldom fails of success at the first bout. To make them, you must mix together black, Dutch pink, and white, using more or less of each colour, according as you would have them darker or lighter. You must make one lay very light, and then put on a thicker, as of the first grounds. You may also make them of other colours, if you please; but these are the most common.

For a day sky, take ultramarine and a good deal of white, and mix them together. With this make a lay, as smooth as you can, with a large pencil and liberal strokes, as for grounds, applying it paler and paler as you descend towards the horizon, which must be done with vermilion or red lead, and with white of the same strength with that where the sky ends, or something less; making this blue lose itself in the red, which you bring down to the skirts of the earth, or tops of houses, and mixing towards the end gall-stone and a good deal of white, in such a manner that the mixture be still paler than the former, without any visible intersection or parting between all these colours of the sky.

When there are clouds in the sky, you may spare the places where they are to be; that is to say, you need not lay on any blue there, but form them, if they are reddish, with vermilion, gall-stone, and white, with a little indigo, and if they are more upon the black, put in a good deal of the last; painting the lights of one and the other with masticot, vermilion, and white, more or less of any of these colours, according to the strength you would give them, or according to that of the original you copy, rounding the whole as you dot (for it is a difficult matter to lay them very smooth at the first painting); and if the sky is not even enough, you must dot it also. It is at your pleasure to exempt the places of the clouds, for you may lay them upon the ground of the sky, heightening the bright parts by putting a good deal of white, and fortifying the shadows by using less. This is the shortest way.

A night or stormy sky is done with indigo, black, and white, mixed together; and the composition is laid as for a day sky. To this mixture must be added ochre, vermilion, or brown red, for the clouds; the lights of which are

to be of masticot or red lead, and a little white, now red-der, now yellower, at discretion. And when it is a tempestuous sky, and lightning appears in some places, be it blue or red, it is to be done as in a day sky, drowning and losing the whole together at the first forming or dead colouring, and at the finishing.

OF DRAPERIES.—To paint a blue drapery, put ultramarine near the white upon your pallet, and mix a part of the one with the other, till it makes a fine pale, and has a body. With this mixture you must form the brightest parts, and then adding more ultramarine, form such as are darker; and go on after this manner till you come to the deepest plaits and the thickest shades, where you must lay pure ultramarine; and all this must be done as for a first forming or dead colouring, that is to say, laying the colour on with free strokes of the pencil, yet as smooth as you can, and losing the lights in the shadows with a colour neither so pale as the light nor so dark as the shades. Then dot with the same colour as in the first forming, but a small degree deeper, that the dots may be fairly seen. All the parts must be drowned one in another, and the plaits appear without intersection. When the ultramarine is not dark enough to make the deeper shadows, how well soever it be gummed, mix a little indigo with it to finish them; and when the extremities of the lights are not bright enough, heighten them with white and a very little ultramarine.

A drapery of carmine is done in the same manner as the blue, except that in the darkest places there is to be a lay of pure vermilion before you dead-colour with carmine, which must be applied at top; and in the strongest shades it must be gummed very much. To deepen it the more, mix a little bistre with it.

There is likewise made another red drapery, which is first drawn with vermilion, mixing white with it to dead-colour the bright places, laying it pure and unmixed for those that are darker, and adding carmine for the grand shades. It is finished afterwards, like other draperies, with the same colours. And when the carmine with the vermilion do not darken enough, work with the first alone, but only in the deepest of the shades.

A drapery of lake is made in the same manner with that of carmine, mixing a good deal of white with it for the bright places, and very little for those that are dark. It is finished likewise with dotting; but you have nothing to do with vermilion in it.

Violet draperies are likewise done after this manner, after making a mixture of carmine and ultramarine, putting always white for the bright parts. If you would have your violet be columbine or dove colour, there must be more carmine than ultramarine; but if you would have it bluer and deeper, put more ultramarine than carmine.

A drapery is made of a flesh colour, beginning with a lay made of white, vermilion, and very pale lake, and making the shades with the same colours, using less white in them. This drapery must be very pale and tender, because the stuff of this colour is thin and light; and even the shades of it ought not to be deep.

To make a yellow drapery, put a lay of masticot over all, then one of gamboge upon that, excepting the brightest places, where the masticot must be left entire; then dead-colour with ochre, mixed with a little gamboge and masticot, putting more or less of the last, according to the strength of the shades. And when these colours do not darken enough, add gall-stone; and gall-stone pure and unmixed is used for the thickest shades, mixing a little bistre with it if there be occasion to make them still darker. You must finish by dotting with the same colours you dead-coloured with, and losing the lights and the shades in one another.

If you put Naples yellow, or Dutch pink, in lieu of mas-

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The green drapery is made by a general lay of verditer, with which, if you find it too blue, mix masticot for the lights, and gamboge for the shades; afterwards add to this mixture lily-green or sap-green, to shadow with; and as the shades are thicker, put more of these last greens, and even work with them pure and unmixed where they are to be extremely dark. You must finish with the same colours, a little darker. By putting more yellow, or more blue, in these colours, you may make different sorts of green, as you please.

To make a black drapery, you dead-colour with black and white, and finish with the same colour, putting more black as the shades are thicker; and for the darkest, mix indigo with it, especially when you would have the drapery appear like velvet. You may always give some touches with a brighter colour, to heighten the lights of any drapery whatsoever.

A white woollen drapery is made by a lay of white, in which there must be a very small quantity of ochre, orpiment, or gall-stone, that it may look a little yellowish. Then dead-colour, and finish the shades with blue, a little black, white, and bistre; putting a great deal of the last in the darkest. The light gray is begun with black and white, and finished with the same colour deeper.

For a brown drapery, make a lay of bistre, white, and a little brown red; and shadow with this mixture made a little darker.

There are other draperies called *variable*, because the lights are of a different colour from the shades. These are mostly used for the vestments of angels, for young and gay people, for scarfs and other airy attire, admitting of a great many folds, and flowing at the pleasure of the wind. The most common are the violets, of which they make two sorts; one where the lights are blue, and the other where they are yellow.

For the first, put a lay of ultramarine and very pale white upon the lights; and shadow with carmine, ultramarine, and white, as for a drapery wholly violet, so that only the grand lights appear blue. Yet they must be dotted with violet in which there is a great deal of white, and lost insensibly in the shades. The other is done by putting upon the lights only, instead of blue, a lay of masticot; working the rest, as in the drapery, all violet, excepting that it must be dotted, and the light parts blended with the shadowy, that is, the yellow with the violet, and the latter with a little gamboge.

The carmine red is done like the last; that is, let the lights be done with masticot, and the shades with carmine, and, to lose the one in the other, make use of gamboge. The lake red is done like that of carmine. The green is done as the lake, always mixing verditer with lily or sap green to make the shades, which are not very dark.

Several other sorts of draperies may be made at discretion, always taking care to preserve the union of the colours, not only in one sort of cloth or so, but also in a group of several figures, avoiding, as much as the subject will allow, the putting of blue near the colour of fire, of green against black; and so of other colours which cut and disjoin, and whose union is not kind enough.

Several other draperies are made of foul colours, as brown, red, bistre, indigo, &c. and all in the same manner; and likewise of other colours, simple and compound; the agreement between which is always to be attended to, that the mixture may produce nothing harsh and disagreeable to the eye. No certain rule can be laid down for this. The force and effect of your colours are only to be known from use and experience, and you must work according to that knowledge.

Linen cloths are done thus: After drawing the plaits or

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They may be done in another manner, by making a general lay of this mixture of ultramarine, black, and very pale white; and dead-colour, as has been said before, with the same colour, but a little deeper. When the shades are dotted and finished, then heighten the lights with pure white, and lose them with the deepening of the linen. But of whatever sort you make them, when they are finished you must give a yellowish tint of orpiment and white to certain places; laying it lightly on, and as it were in water, so that what is underneath may notwithstanding plainly appear, as well the shadows as the dotting.

Yellow linen cloth is done by putting a lay of white, mixed with a little ochre. Then form and finish the shades with bistre, mixed with white and ochre, and in the thickest shades use pure bistre; and before you finish, give some tints here and there of ochre and white, and others of white and ultramarine, as well upon the shades as the lights, but let them be very bright; then drown the whole together in dotting, and it will look finely. As you finish, heighten the extremities of the lights with masticot and white. You may add to this sort of linen, as well as to the white, certain bars from space to space, as in Turkey mantuas, that is, small stripes blue and red with ultramarine and carmine; one of red between two of blue, very bright and clear upon the lights, and deeper upon the shades. Virgins are pretty often dressed with veils of this sort, and scarfs of this kind are put about necks that are bare, because they become the tint mighty well.

If you would have both these sorts of linen transparent, and the stuff or other thing that is beneath appear through them, make the first lay for them very light and clear, mix in the colour to shadow with a little of that which is underneath, especially towards the end of the shades, and only do the extremities of the lights, for the yellow, with masticot and white, and for the white, with pure white.

They may be done in another manner, especially when you would have them altogether as clear as muslin, lawn, or gauze. To this end form and finish what is to be beneath, as if nothing was to be put over it. Then mark out the light and clear folds with white or masticot; and a shadowy one with bistre and white, or with black, blue, and white, according to the colour you would make them of; making the rest somewhat fainter; yet this is not necessary except for the parts that are not to be so clear.

Crape is done in the same way, excepting that the folds of the shades and the lights, and the borders too, are to be marked out with little filaments of black upon what is underneath; which is likewise to be finished beforehand.

When you would make a stuff like a watered tabby, make the waves upon it with a colour a little lighter or a little darker in the lights and the shades.

There is a manner of touching draperies which distinguishes the silken from the woollen. The last are more terrestrial and sensible; the others more light and fading. But it must be observed, that this is an effect which depends partly upon the stuff and partly upon the colour; and, for the employing of these in a manner suitable to the subjects and the deepening of painting, we shall here touch upon their different qualities.

We have no colour which partakes more of light, or which comes nearer the air, than white; which shows it

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to be fickle and fleeting. It may, nevertheless, be held and brought to by some neighbouring colour, more heavy and sensible, or by mixing them together. Blue is a most fleeting colour, and so we see that the sky and the remotest views of a picture are of this colour; but it will become lighter and ficker in proportion as it is mixed with white. Pure black is the heaviest and most terrestrial of all colours; and the more of it you mix with others, the nearer you bring them to the eye.

For the doing of lace, French points, or other things of that nature, put over all a lay of blue, black, and white, as for linen; then heighten the flowerwork with pure white, afterwards make the shades above with the first colour, and finish them with the same. When they are upon the carnation or naked parts of a picture, or upon any thing else that you would show through another, finish what is beneath, as if nothing was to be put over it; and at the top, make the points or lace with pure white, shadowing and finishing them with the other mixture.

If you would paint a fur, you must begin with a kind of drapery, done, if it be dark, with bistre and white, making the shadings of the same colour, but with less white. If the fur be white, do it with blue, white, and a little bistre; and when this beginning, or first-forming, is done, instead of dotting, draw small strokes, turning, now in one manner, now in another, according to the course and flattening of the hair; then heighten the lights of dark furs with ochre and white, and of the other with white and a little blue.

For doing a building, if it be of stone, take indigo, bistre, and white, with which make the beginning or first form thereof; and for shading it, put less of this last, and more bistre than indigo, according to the colour of the stone you would paint. To these you may likewise add a little ochre, both for the forming and the finishing. But to make it finer, you must give, here and there, especially for old fabrics, blue and yellow tints, some with ochre, and others with ultramarine, mixing always white with them, whether before the first-forming, provided they appear through the draught, or after it, losing or drowning them with the rest when you finish.

When the building is of wood, as there are many sorts, it is done at discretion; but the most ordinary way is to begin or first-form with ochre, bistre, and white, and finish without white, or with very little; and if the shades are deep, with pure bistre. In the other, vermilion is sometimes added, sometimes green or black, according to the colour they would give it; and they finish with dotting, as in draperies and every thing else.

OF CARNATIONS.—There are in carnations so many different colourings, that it would be a difficult thing to give general rules upon so variable a subject. Nor are they minded, when one has got, by custom and practice, some habit of working easily; and such as have arrived at this degree employ themselves in copying their originals, or else they work upon their ideas, without knowing how; insomuch that the most skilful, who do it with less reflection and pains than others, would likewise be more puzzled to give an account of their maxims and knowledge in the matter of painting, if they were to be asked what colours they made use of for such and such a colouring, a tint here, and another there.

Nevertheless, as beginners want some instruction at the first, we shall show in general after what manner several carnations are to be done.

In the first place, after having drawn the proposed figure with carmine, and ordered the piece, apply, for women and children, and generally for all tender colourings, a lay of white, mixed with a very little of the blue made for faces, of which we have mentioned the composition; but let it hardly be seen. For men, instead of blue, put in this first lay a little vermilion; and when they are old, a little ochre

is mixed with it. Afterwards follow all the traces with vermilion, carmine, and white, mixed together; and begin all the shades with this mixture, adding white in proportion as they are weaker, and putting but little in the darkest, and almost none in certain places where strong touches are to be given; for instance, in the corner of the eye, under the nose, at the ears, under the chin, in the separations of the fingers, in all joints, at the corners of the nails, and generally in every part where you require to mark out separations in shades that are obscure. Neither need you fear to give to those places all the force and strength which they ought to have as soon as you begin or first-form them, because, in working at the top with green, the red you have put there is always weakened.

After having begun, or first-formed, or dead-coloured, with red, make blue tints with ultramarine and a great deal of white, upon the parts which fly from the eye; that is to say, upon the temples, under and in the corners of the eyes, on both sides of the mouth, above and below, a little upon the middle of the forehead, between the nose and the eyes, on the side of the cheeks, and on the neck and other places where the flesh assumes a bluish cast. Yellowish tints are likewise made with ochre or orpiment, and a little vermilion mixed with white, under the eyebrows, on the sides of the nose towards the bottom, a little underneath the cheeks, and upon the other parts which rise and come nearer the eye. It is especially from these tints that the natural complexion is to be observed in order to catch it; for painting being an imitation of nature, the perfection of the art consists in the justness and simplicity of the representation, especially in face-painting.

When, therefore, you have done your first lay, your dead-colouring, and your tints, you must work upon the shades, dotting with green for the carnations or naked parts, mixing, according to the rule we have given for the tints, a little blue for the parts which fly from the eye; and, on the other hand, making it a little yellower for those which are more sensible, that is to say, which rise, and come nearer the eye; and at the end of the shades, on the side of the light, you must blend and lose your colour insensibly in the ground of the carnation, with blue, and then with red, according to the places where you paint. If this mixture of green does not work dark enough at first, pass over the shades several times, now with red, and now with green, always dotting; and this do until they are as they should be. And if you cannot with these colours give the shades all the force which they ought to have, finish, in the darkest, with bistre mixed with orpiment, ochre, or vermilion, and sometimes with pure bistre, according to the colouring which you would make, but lightly, laying on your colour very clearly.

You must dot upon the clear and bright places with a little vermilion or carmine, mixed with much white, and a very small quantity of ochre, in order to lose them with the shady, and to make the tints die away insensibly into one another; taking care, as you dot, or hatch, to make your strokes follow the turnings and windings of the fleshy parts. For although the rule be to cross always, this dotting or hatching ought to appear a little more here, because it rounds the parts; and as this mixture might make a colouring too red, if it were always to be used, artists work likewise in every part, to blend the tints and the shades with blue and a little green, and much white, so mixed as to be very pale; excepting, nevertheless, that this colour must not be put upon the cheeks, nor upon the extremities of the clear parts, no more than the other mixture upon these last, which must be left with all their light, as certain places of the chin, of the nose, and of the forehead, and upon the cheeks, which ought nevertheless to be redder than the rest, as well as the feet, the hollows of the hands, and the fingers of both.

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Observe, that these two last mixtures ought to be so pale that the work shall hardly be visible; for they serve only to soften it, to unite the tints with one another, and the shades with the lights, and to drown the traces. Care must likewise be taken that you work not too much with the red mixture upon the blue tints, nor with the blue upon the others; but change the colour from time to time when you perceive that it works too blue or too red, till the work be finished.

The white of the eyes must be shaded with this same blue, and a little flesh colour; and the corners, on the side of the nose, with vermilion and white, giving them a little touch of carmine. The whole is softened with this mixture of vermilion, carmine, white, and a very small matter of ochre.

The apples or balls of the eyes are done with the mixture of ultramarine and white, the last prevailing a little; adding a little bistre if they are yellowish, or a little black if they are gray. Make the little black circle in the middle, called the *crystal of the eye*, and shade the balls, with indigo, bistre, or black, according to the colour they are of; giving to each a small touch of pure vermilion round the crystal, which must be lost with the rest at the finishing. This gives vivacity to the eye.

The round or circumference of the eye is done with bistre and carmine, that is to say, the slits or partings, and the eyelids, when they are large and bold, especially the upper ones; which must afterwards be softened with the red or blue mixtures we have mentioned before, that they may be lost in one another, and nothing seem intersected. When this is done, give a little touch of pure white upon the crystal, on the side of the lights. This makes the eye shine, and gives life to it.

The mouth is dead-coloured with vermilion mixed with white, and finished with carmine, which is softened like the rest; and when the carmine does not work dark enough, mix a little bistre with it. This is to be understood of the corners in the separation of the lips, and particularly of certain mouths half open.

The hands, and all the other parts of carnation, are done in the same manner as the faces, observing that the ends of the fingers be a little redder than the rest. When your whole work is formed and dotted, mark the separations of all the parts with little touches of carmine and orpiment mixed together, as well in the shady as in the light places, but a little deeper and stronger in the first, and lose them in the rest of the carnation.

The eyebrows and the beard are dead-coloured, as are the shades of carnations, and finished with bistre, ochre, or black, according to the colour they are of, drawing them by little strokes the way they ought to go; that is to say, give them all the nature of hair. The lights must be heightened with ochre and bistre, a little vermilion, and much white.

For the hair of the head, make a lay of bistre, ochre, and white, and a little vermilion; and when it is very dark coloured, use black instead of ochre. Afterwards form the shady parts with the same colours, putting less white in them; and finish with pure bistre, or mixed with ochre or black, by small strokes, very fine, and close to each other, waving and buckling them according to the curling of the hair. The light parts must also be heightened by little strokes with ochre or orpiment, white, and a little vermilion; after which, lose the lights and the shades in each other, by working sometimes with a dark and sometimes with a light colour.

And for the hair about the forehead, through which the skin is seen, it must be first-formed with the colour thereof, and that of the carnation, working and shading with one and the other, as if you designed to paint none; then form it, and finish with bistre. The lights are to be

heightened as the other. Gray hair is dead-coloured with white, black, and bistre, and finished with the same colour, but deeper, heightening the bright and clear parts of the hair, as well as those of the eyebrows and the beard, with white and very pale blue, after having formed them; as the others, with the colour of the flesh or skin; then finish with bistre.

But the most important thing is to soften one's work; to blend the tints in one another, as well as the beard and the hair about the forehead, with the other hair and the carnation; taking especial care not to work rough and dry, and not to intersect the traces, turnings, and windings of the carnation or naked parts. You must likewise accustom yourself to put white in your colours only in proportion as you work lighter or darker; for the colour you use the second time must always be a little stronger and deeper than the first, unless it be for softening.

Different colourings are easily made, by putting more or less of red, or blue, or yellow, or bistre, whether for the dead-colouring or for the finishing. That for women ought to be bluish; that for children a little red; and both fresh and florid. That for men should be yellower, especially when they are old.

For painting fire and flames, the lights are done with masticot and orpiment; and for the shades, vermilion and carmine are mixed. A smoke is done with black, indigo, and white, and sometimes with bistre; one may likewise add vermilion or ochre, according to the colour required for it.

Pearls are painted by putting a lay of white, and a little blue; they are shaded and rounded with the same colour, deeper; a small white dot is made almost in the middle, on the side of the light; and on the other side, between the shadow and the edge of the pearl, a touch is given with masticot, to make the reflection; and under the pearls is made a little shadow of the colour of the ground they are upon.

Diamonds are represented with pure black; then they heighten them with little touches of white on the side of the light. It is the same thing for any other jewels you have a mind to paint; there is nothing to be done but to change the colour. For making a figure of gold, put a lay of shell-gold, and shade it with gallstone. Silver is done the same way, excepting that it must be shaded with indigo.

One great means of acquiring a perfection in the art, is to copy excellent originals. We enjoy with pleasure and tranquillity the labour and pains of others. But a man must copy a great number before he is able to produce as fine effects; and it is better to be a good copyist than a bad original.

OF LANDSCAPES.—In the first place, after having ordered the economy of your landscape in the same way as that of your other pieces, you must form the nearest grounds or lands, when they are to appear dark, with sap or lily green, bistre, and a little verditer, to give a body to your colour; then dot with this mixture, but a little darker, adding sometimes a little black to it. For such pieces of ground as the light falls upon, and as are therefore clear and bright, make a lay of ochre and white, then shade and finish with bistre. In some a little green is mixed, particularly for shading and finishing.

There are sometimes upon the fore part certain reddish lands, which are dead-coloured with brown-red, white, and a little green, and finished with the same, putting a little more green in them.

For the making of grass and leaves upon the foreground, you must, when that is finished, form with sea-green, or verditer, and a little white; and for those that are yellowish, mix masticot. Afterwards shade them with lily-green, or bistre and gallstone, if you would have them appear withered. The grounds or lands at a little distance

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are formed with verditer, and shaded and finished with sap-green, adding bistre for some of the touches here and there. Such as are at a greater distance are done with sea-green and a little blue, and shaded with verditer. In a word, the farther they go, the more bluish they are to be made; and the farthest distance ought to be of ultramarine and white, mixing in some places small touches of vermilion.

Water is painted with indigo and white, and shaded with the same colour, but deeper; and to finish it, instead of dotting, nothing is done but making strokes and traces without crossing, and giving them the same turn with the waves when there are any. Sometimes a little green must be mixed in certain places, and the light and clear parts heightened with pure white, particularly where the water foams.

Rocks are dead-coloured like buildings of stone, excepting that a little green is mixed for forming and shading them. Blue and yellow tints are made upon them, and lost with the rest in finishing; and when there are small branches, with leaves, moss, or grass, when all is finished, they are raised at the top with green and masticot. They may be made yellow, green, and reddish, for appearing dry, in the same manner as on the ground. Rocks are dotted like the rest; and the farther they are off the more grayish they are represented.

Castles, old houses, and other buildings of stone and wood, are done in the manner above mentioned; speaking of those things, when they are upon the first lines. But when you would have them appear at a distance, you must mix brown, red, and vermilion, with much white, and shade very tenderly with this mixture; and the farther they are off, the weaker are the strokes to indicate the separations. If they are covered with slate, it is to be made bluer than the rest.

Trees are not done till the sky be finished; one may, nevertheless, spare the places of them when they contain a good number; and, however it be, such as come near to the eye are to be dead-coloured with verditer, mixing sometimes ochre, and shaded with the same colours, adding lily-green. Afterwards you must work leaves upon them by dotting without crossing; for this must be done with small elongated dots, of a darker colour, and pretty full of it, which must be conducted on the side of the branches, by little tufts of a little darker colour. Then heighten the lights with verditer or sea-green, and masticot, making leaves in the same manner; and when there are dry branches or leaves, they are dead-coloured with brown-red or gallstone, and white, and finished with gallstone without white, or with bistre.

The trunks of trees are to be dead-coloured with ochre, white, and a little green, for the light and clear parts; and for the dark, black is mixed, adding bistre and green for shadowing the one and the other. Blue and yellow tints are likewise made upon them, and little touches given here and there with white and masticot, such as may ordinarily be seen upon the bark of trees.

The branches which appear amongst the leaves are done with ochre, verditer, and white, or with bistre and white, according to the light which they are placed in. They must be shaded with bistre and lily-green.

Trees which are at a little distance are dead-coloured with verditer and sea-green, and are shaded and finished with the same colours, mixed with lily-green. When there are some which appear yellowish, lay with ochre and white, and finish with gallstone. For such as are in the distances and remote views, you must dead-colour with sea-green, with which, for finishing, you must mix ultramarine; and heighten the lights of one and the other with masticot, by small disjointed leaves. It is the most difficult part of landscape, in the manner of miniature, to leaf a tree

well. To learn, and break one's hand to it a little, the way is to copy good ones; for the manner of touching them is singular, and cannot be acquired except by working upon trees themselves, in regard to which you must observe to make little boughs, which must be leafed, especially such as are below and toward the sky.

OF FLOWERS.—It is a general rule, that flowers are designed and laid like other figures, but the manner of forming and finishing them is different; for they are first-formed only by large strokes and traces, which you must turn at the first the way the small ones are to go, with which you finish, and this turning will aid much therein. And for finishing them, instead of hatching or dotting, you must draw small strokes, very fine, and very close to one another, without crossing; repassing several times, till your dark and your clear parts have all the force which you desire to give them.

Of Roses.—After making your first sketch, draw with carmine the red rose, and apply a very pale lay of carmine and white; then form the shades with the same colour, putting less white in it; and lastly, with pure carmine, but very bright and clear at the first, fortifying it more and more as you proceed in your work, and according to the darkness of the shades. This is done by large strokes. Then finish, working upon it with the same colour by little strokes, which you must make go the same way with those of the engraving, if it be a print you copy; or the way the leaves of the rose turn, if you copy after a painting, or after nature; losing the dark in the clear parts, and heightening the greatest lights, and the brightest or most lightsome leaves, with white and a little carmine. You must always make the hearts of roses, and the side of the shadow, darker than the rest; and mix a little indigo for shading the first leaves, particularly when the roses are blown, to make them seem faded. The seed is dead-coloured with gamboge, with which a little sap-green is mixed for shading. Roses streaked with several colours ought to be paler than others, that the mixture of colours may be better seen; which is done with carmine, a little darker in the shades, and very clear in the lights, always hatching by strokes. For white roses you must put a lay of white, and form and finish them as the red, but with black, white, and a little bistre; and make the seed a little yellower. Yellow roses are done by putting in every part a lay of masticot, and shading them with gamboge, gallstone, and bistre, heightening the clear and light places with masticot and white.

The styles, the leaves, and the buds of all sorts of roses are formed with verditer, with which is mixed a little masticot and gamboge; and for shading them, sap-green is added, putting less of the other colours when the shades are deep. The outside of the leaves ought to be bluer than the inside; wherefore it must be dead-coloured with sea-green, and sap-green mixed with that for shading, making the veins or fibres upon this side clearer than the ground, and those upon the other side darker. The prickles which are upon the styles and buds of roses are done with little touches of carmine, which are made to go every way; and for those which are upon the stalks, they are formed with verditer and carmine, and shaded with carmine and bistre, making the bottom of the stalks more reddish than the top, that is, carmine and pure bistre being mixed with the green.

Of Tulips.—As there is an infinity of tulips, different from one another, we cannot pretend to mention the colours with which they are all done. We shall only touch upon the handsomest, called *streaked*, in which the streaks are dead-coloured with very clear carmine in some places, and with darker in others, finishing with the same colour by little strokes, which must be carried the same way with the streaks. In others is put first a lay of vermilion;

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Miniature Painting. then they form them by mixing carmine, and finish them with pure carmine. In some they put Florence lake over the vermilion instead of carmine, whilst others are done with lake and carmine mixed together, and with lake alone, or with white and lake for the first-forming, whether it be rose pink or Florence lake. There are others, again, of a purple colour, which are formed with ultramarine, carmine, or lake, sometimes bluer and sometimes redder. The manner of doing both one and the other is the same; there is no difference except in the colours. You must, in certain places, as between the streaks of vermilion, carmine, or lake, sometimes put blue made of ultramarine and white, and sometimes a very bright purple, which is finished by strokes like the rest, and lost with the streaks. There are some likewise which have sallow tints, that are made with lake, bistre, and ochre, according as they are found requisite; but this is only in fine and rare tulips, and not in the common ones. For shading the bottom of them, indigo and white are ordinarily taken for those whose streaks are of carmine; but for such as are of lake, black and white are taken, with which, in some, bistre is mixed, and in others green. Some are likewise to be shaded with gamboge and umber, and always by strokes and traces which turn as the leaves turn. Other tulips are likewise done, which are called *bordered*; that is to say, the tulip is not streaked except on the edges of the leaves, where there is a border. It is white in the purple, red in the yellow, yellow in the red, and red in the white. The purple is laid on with ultramarine, carmine, and white, and the shading and finishing is done with this mixture. The border is spared; that is to say, let only a light lay of white be put there, and let it be shaded with very bright indigo. The yellow is formed with gamboge, and shaded with the same colour, mixing with it ochre and umber or bistre. The border is laid with vermilion, and finished with a very small matter of carmine. The red is formed with vermilion, and finished with the same colour, mixing with it carmine or lake. The bottom and the border are done with gamboge; and, for finishing, it is usual to add gallstone and umber, or bistre. The white is shaded with black, blue, and white. Indian ink is very proper for this. The shadings of it are very delicate; and it produces alone the effect of blue and white, mixed with the other black. The border of this white tulip is done with carmine. In all these sorts of tulips, a nerve or sinew is left in the middle of the leaves which are brighter than the rest, and the borders are drowned at the bottom by small traces, turning crossways; for they must not appear to be cut and separated, like the streaked or party-coloured. They are likewise represented of several other colours. When they happen to be of that kind the bottoms of which on the inside are black, as it were, it is usual to form and finish them with indigo, as also the seed about the nozzle or stalk; and if the bottom is yellow, it is formed with gamboge, and finished by adding umber or bistre. The leaves and the stalks of tulips are ordinarily formed with sea-green, and shaded and finished with lily-green, by large traces all along the leaves. Some may likewise be done with verditer, mixing with it masticot, and shaded with sap-green, that the green of the shades may be yellower.

The Carnation and Pink.—It is with pinks and carnations as with anemonies and tulips; that is, there are some of mixed colours, and others of one single colour. The first are streaked and diversified, sometimes with vermilion and carmine, sometimes with pure lake or with white; certain streaks being very dark and others very pale. Their bottoms are ordinarily shaded with indigo and white. There are pinks of a very pale flesh colour, and streaked and diversified with another a little deeper, made with vermilion and lake. Some of them, which are of lake and white, are shaded and streaked without white; others, which

are all red, are done with vermilion and carmine as dark as possible; others are all of lake; and, lastly, there are others, in which nature or fancy is the only rule. The green of one and the other is sea-green, shaded with lily-green or sap-green.

Painting in oil has its advantages, were they only these: that it exhibits more work, and takes up less time. It is likewise better defended against the injuries of time; and the right of birth must be granted it, as well as the glory of antiquity. But miniature painting has likewise its advantages; and, without repeating such as have been already mentioned, it is neater and more commodious. You may easily carry all your implements in your pocket, and work whenever and wherever you please, without a number of preparations. You may quit and resume it as often as you please, and its elegance is only surpassed by its convenience.

MINIM, in *Music*, is a note equal to two crotchets, or half a semibreve.

MINIMS, a religious order in the church of Rome, founded by St Francis de Paulo, towards the close of the fifteenth century. Their habit is a coarse black woollen stuff, with a woollen girdle of the same colour, tied in five knots. They are not permitted to quit their habit and girdle by day or by night. Formerly they went barefooted, but they are now allowed the use of shoes.

MINIMUM, in the higher geometry, the least quantity attainable in a given question.

MINING, the art of working mines, or of extracting minerals and mineral ores from the bowels of the earth.

This includes the scientific knowledge necessary for opening and working mines, and preparing the ores for use; it requires an intimate acquaintance with mineralogy and geology, as well as the different processes by which mines may be wrought to advantage, useful minerals searched out and brought to the surface, and means employed for mechanically and chemically separating metals from their ores; besides the essential operations of sinking shafts, driving galleries and adit levels, removing all difficulties which occur in the course of the work, propping up the superincumbent earth or rock so as to give security to the miners, and constructing the machinery necessary either for draining mines or performing the requisite operations in the preparation and reduction of ores. The preparation of ores consists in breaking asunder the larger pieces, and then purifying them by means of water from the earth which adheres to them; in the separation of the coarser substances from the finer, by means of a sieve moved up and down in water; in the crushing of the ore in stamping-mills, by means either of hammers or iron cylinders; and, lastly, in the separation of the metallic substances from the stone or earth with which they are combined, by washing the crushed ore in troughs or on inclined tables crossed by a current of water, so that the heavier ore may remain, whilst the lighter substances are carried away by the stream of water. Mining further includes the final purification of the ore by amalgamation or otherwise, and its reductions by means of fusion. In the case where the object of mining is to obtain a mineral substance, as coal, which is fit for immediate use when brought to the surface, that term is employed in a more restricted sense, being limited to the operations which are requisite for the simple extraction and bringing up from the pit or mine the mineral in question.

I. The application of science to the art of practical mining has hitherto been made only to a limited extent. Yet the theory of the formation of mineral and metallic substances, and the rules which may lead to their discovery, are objects of much greater national importance than is commonly supposed. The circumstances under which minerals are usually found, the mode of obtaining them, and

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their probable extent and value, are inquiries which, whilst they must ever be highly interesting to the man of science, who seeks knowledge for its own sake, are altogether essential to the mining proprietor, as affording the only means by which he can form a correct judgment respecting the mode of working adopted by the practical miner.

The advantage to be derived from a knowledge of well-established facts respecting the arrangement and distribution of mineral substances, will be best illustrated by examples of the errors and oversights committed where this knowledge was wanting. It is generally known that, for some years, lime was exported to New South Wales, where it exists in abundance in its natural state. In Cornwall, ores of silver and cobalt were, until recently, thrown away from a mine which has, since the discovery of their value, returned upwards of L.10,000 a year from these ores; and in the same country, although celebrated for its tin mines from the earliest periods of history, yet, until last century, the ores of copper were employed only to repair the roads. Wherever the copper appeared in a lode, it was a common expression that the ore came in and "spoiled the vein;" and, even in the present day, but little attention is paid to whatever is not manifestly either tin or copper, or known to yield these metals. In Derbyshire, although lead has been smelted from the common blue ore ever since the time of the Romans, the other ores of the same metal were never thought of, but left in heaps, as rubbish; yet we have lived to see a public road, made and repaired with these rejected ores, actually taken up and smelted to good account. Instances might also be mentioned of persons who, in the belief that their estates contained valuable mineral veins, engaged in expensive workings, and sometimes ruined their fortunes; when a slight acquaintance with geology would have served to convince them that a successful result, if not impossible, was at least highly improbable. As to the practical miner, he is altogether the creature of habit, holding geology in but little estimation, and smiling at the nice distinctions of the mineralogist. Hence, if any inquiry be made of him respecting the interesting phenomena of veins, he generally prefers the theory of his forefathers to that which has been deduced from the results of more recent and accurate investigations.

In this country no public means have been employed for removing ignorance and counteracting prejudice in regard to the working of mines. But the case is different on the continent. Both France and Germany possess national institutions for facilitating the study of the sciences applicable to mining operations; and the advantage of such a course of education is sufficiently demonstrated by the fact, that the companies formed for working mines in South America and Brazil have given a decided preference to mining officers trained in the schools of France and of Germany. Besides, of all speculative employments, mining is perhaps the most uncertain. Experience and ingenuity are frequently baffled; the most promising appearances often end in disappointment; whilst from veins which some persons have abandoned in despair, others have frequently derived enormous profits. This very uncertainty, however, only affords another argument for concentrating all the lights of science, in order as far as possible to lessen the risk of disappointment, and to afford the miner some surer guide than chance or caprice in pursuing his exploratory labours.

It may be observed generally, that the materials which compose the crust, if not the body, of the earth, are variously distributed, yet preserve their relative positions, from the surface downwards to the greatest depths hitherto obtained; those substances which consist of homogeneous matter being collected together and deposited either above or below a similar stratum of other substances in a con-

tinued series of depositions. That these deposits were originally parallel with the earth's surface may be reasonably supposed, and indeed appears to admit of almost no doubt; yet by some great convulsion of nature, some prodigious force acting upwards, the strata have been raised and broken through, whilst the corresponding parts being raised and depressed in different directions, the edges of the whole series have been elevated to the surface in an uniform curve or right line, appearing in the side of a cliff or mountain, or protruding in enormous masses of great extent and altitude; at the same time that the lower stratum still preserves the same relative position which it assumed in its original formation. By attending to this important fact, geologists are enabled to ascertain the order of stratification in any country or district, and thence to form a tolerably correct opinion respecting its mineral contents to a much greater depth than can ever be reached by mining operations.

If, for instance, the stratum be found to dip at a certain angle, by observing carefully the superincumbent strata, we may at once discover not only the depth at which a shaft proposed to be sunk will cut the stratum sought, but also the nature of the strata to be passed through in its course. The superincumbent strata will sometimes be found to vary in thickness, and a proportional allowance must then be made in the working for this deviation from the previous estimate. When the strata descend in the line of their dip or inclination, the depth to which they reach beneath the surface is unknown; but they are seldom found to continue their descent very far at the same angle, and are either curved in the coal formation, bent in another direction, or altogether dislocated. In the upper series or formation, the strata are not uniform in their construction, but are intersected by fissures resembling the bottom of a muddy pool dried up by the sun; and these cavities, when empty, are sometimes of great extent. Eldon Hole, and the other subterranean wonders of the Peak in Derbyshire, may be cited as remarkable examples of such dislocations. These fissures, however, are commonly filled with mineral substances, or metalliferous ores, in which case they are termed *veins*; their inclination generally ranges from 45° to the vertical, or 90°; and their course downwards, like that of the strata, is seldom terminated within the limits of human labour and research. But some cases have nevertheless occurred where the metallic produce has to all appearance been worked out, or where the vein has branched into filamentous portions at two or three hundred feet below the surface.

Formerly the richest part of a vein of copper ore was supposed to be situated at a depth of from forty to fifty fathoms, and that of a vein of tin at from twenty to sixty fathoms; but experience derived from the deep workings carried on in Cornwall has proved this idea to be erroneous. When a vein or stratum is terminated abruptly, by the crossing of another vein or stratum in a transverse direction, or by perpendicular fissures filled with alluvial matter, this is not considered as a termination of the vein, which, in fact, is only broken off or disjoined, and may again be discovered by searching in the analogous part on the opposite side of the deranged strata. As to the methods employed in following a metalliferous vein when broken off by faults or dykes, these are necessarily various, according to circumstances; and it is in such cases that the practical knowledge and experience of the miner are of far more avail than all the suggestions of theory. Veins occur in almost every species of rock, and vary in thickness from a mere filament to many fathoms; they are very unequal in the different parts of their course, but they are commonly widest above. Narrow veins are usually short, whilst those of considerable breadth extend to a great distance. The silver vein of Veta Madre, at Guanaxuato, has been work-

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The principal metalliferous veins in England take a direction from east to west. When two veins running nearly parallel meet and join, they produce a good body of ore at the point of junction. If the principal vein dip at a less angle than the secondary one, it is usually found to be enriched by the latter; but if it dip at a greater angle, it is impoverished in like proportion. Sometimes a vein is joined by another, which, after falling into its course, and continuing for some distance to run parallel to it, suddenly resumes its original state, and breaks off in a different direction. For the most part, tin and lead lie nearer the surface than copper. Where the latter is met with in large masses, the vein commonly falls off shortly afterwards; but when the lode is found spotted with small portions of copper ore, there is a strong presumption that the produce will be rich and lasting. A large and productive vein is usually accompanied by others which fall into the main lode. The abundance of water in a lode is considered as a promising indication, inasmuch as dry veins are never very rich in ore. Lodes consist of hard solid stone, or less compact, soft, and crumbling materials. If the adjoining strata contain much spar and quartz, then the metalliferous ore in the lode is found in a solid, hard, stony substance; but when nature has been more sparing of her cement, the ore is generally met with in a loose and rubbly state.

Experience has shown that certain minerals and metals are more frequently found attached to particular rocks than to other materials, and that some of them are discovered only in particular strata. Metalliferous veins are generally encompassed with some stone or other substance peculiar to the mine, which, from the appearance of the rock, apprises the miner of his approach to the vein. It has been ascertained that the arrangement of the materials of the earth is to a certain extent regular and uniform. Hence, when we know the particular substances near which certain metals and minerals are generally found, together with their usual disposition in the strata; and when, in another situation, we meet with the same materials similarly disposed; we may conclude with tolerable confidence, that the metal or mineral we are in quest of is not far distant, and that the operations may be continued with a reasonable prospect of success. Where a bed of mineral produce exists, it may be expected to extend throughout a considerable tract of country; but, from the curvature of formation, or from dislocation of the strata, it may nevertheless disappear at a particular point, and be lost, until it again rises to the "outcrop," or is accidentally met with

Mining. in boring or sinking a shaft at a considerable distance from the original working.

For the more complete elucidation of what has been stated above, we shall now describe shortly the several formations, with their general characteristics, the minerals which are usually found in them, and the localities in which the most important mines are situated.

The rocky masses composing the crust of the globe consist either of simple homogeneous bodies, as limestone; or of an aggregation of two or more simple materials, as granite. In some strata no organic remains whatever have been discovered; in others the fossil remains of animal and vegetable matter are of frequent occurrence. This diversity of character is the foundation of an arrangement, according to which rocks are divided into primary and secondary. The rocks belonging to the primitive formation are found under every other stratified mass, and never resting upon nor covering any; they follow a certain invariable order of succession, and exhibit determinate relations with other strata. Thus, granite is never found alternating with sandstone, nor gneiss covering a bed of coal. In mountainous countries, the primitive formation, upheaved in Alpine chains, offers itself to our notice in stupendous masses, having the strata of other formations resting upon and supported by their bases; or, as sometimes happens, without such formations altogether. Primitive rocks contain, either occasionally or exclusively, almost every metal hitherto discovered. They may be classed, in the usual order of their occurrence, under the denominations of granite, gneiss, mica slate, topaz rock, clay slate, porphyry, trap, limestone, serpentine, quartz, gypsum, flint slate, and syenite. Their component minerals are quartz, hornblende, felspar, mica, and limestone.

Granite is supposed to be the most ancient and most abundant of all substances. It forms the base and sometimes the whole mass of mountains; it constitutes a part of the Alps and the Pyrenees, the mountains of Cornwall, Saxony, and Silesia, the grand chain of the Ural and Altai in Asia, the Atlas in Africa, and the Andes and Cordilleras in South America. It is formed by a concretion of the granular particles of felspar, quartz, and mica, irregularly mingled, strongly adherent, and evidently the effect of simultaneous crystallization. The size, colour, and relative proportions of the particles differ greatly, but felspar with a reddish tint generally predominates. It is one of the hardest and most durable rocks known. Granite is much less metalliferous than any other of the primitive rocks; but it nevertheless yields tin and iron in considerable quantities, rarely gold or silver, and sometimes, in minute veins, molybdena, lead, copper, zinc, manganese, bismuth, galena, and blende.

Gneiss is immediately incumbent on granite, and is composed of the same substances; but mica, being more abundant, forms a granular slaty mass. This rock is rich in mineral produce; indeed all the useful metals, excepting quicksilver, are found in it, sometimes in beds, but more frequently in veins. The greater part of the mines in Saxony and Bohemia are in gneiss mountains. In the vicinity of Freyberg more than two hundred veins of silver, lead, tin, copper, and cobalt, have been worked in gneiss; and the silver mines of Königsberg are in the same rock. It is abundant in Scotland and the isles adjacent; and also in South America and the United States.

Mica slate, or schistus, is composed of mica and quartz. It has a slaty structure, mica being the chief ingredient; its colour is gray tinted with green or yellow, sometimes brown; and it differs from gneiss, upon which it rests, by being disposed in leaves rather than in distinct scales. It contains beds of magnetic iron ore; iron, copper, and arsenical pyrites; red iron ore, lead glance, blende, gold, and cobalt; whilst in the veins are found similar ores to

Mining. those discovered in gneiss. The mines of Dalecarlia and Fahlun in Sweden, the gold mines of Monte Rose, some of those in Salzburg, the silver mines of Johann-Georgenstadt and Bransdorf, and many others, are in this rock. It is also common in Scotland, on the continent, and in many other parts of the globe.

Topaz rock is of very inconsiderable extent, and is hardly to be considered as a distinct species. It is composed of quartz, tourmaline, topaz, and lithomarge, in granular concretions; but it has hitherto been met with only in Saxony, where it forms a rock which is known by the name of *schneckenstein*.

Clay slate is a simple rock, sometimes forming entire mountains; but the cliffs are not so steep and rugged as in granite and gneiss formations; and it is also much more favourable to vegetation. One of the varieties of this stratum is the well-known material for covering roofs of buildings; the rest partake of its general characters. It passes by different gradations into mica slate, acquiring a glistening lustre in its approach to that formation; it is distinctly stratified, and is rich in metal, containing tin, lead, cobalt, silver, pyrites, copper ore, and sometimes gold. The veins in Cornwall often run in *killas*, which is a variety of clay slate; and some curious phenomena occur in their passage through the strata. If the vein contain tin ore in the granite, it will frequently change to copper in the *killas*; and if tin be abundant in the *killas*, copper will supply its place in the granite. This rock is very widely distributed, and occurs in all parts of the world. In Saxony, Bohemia, Hungary, and in North and South America, mines are worked in it, some of them to a very considerable extent.

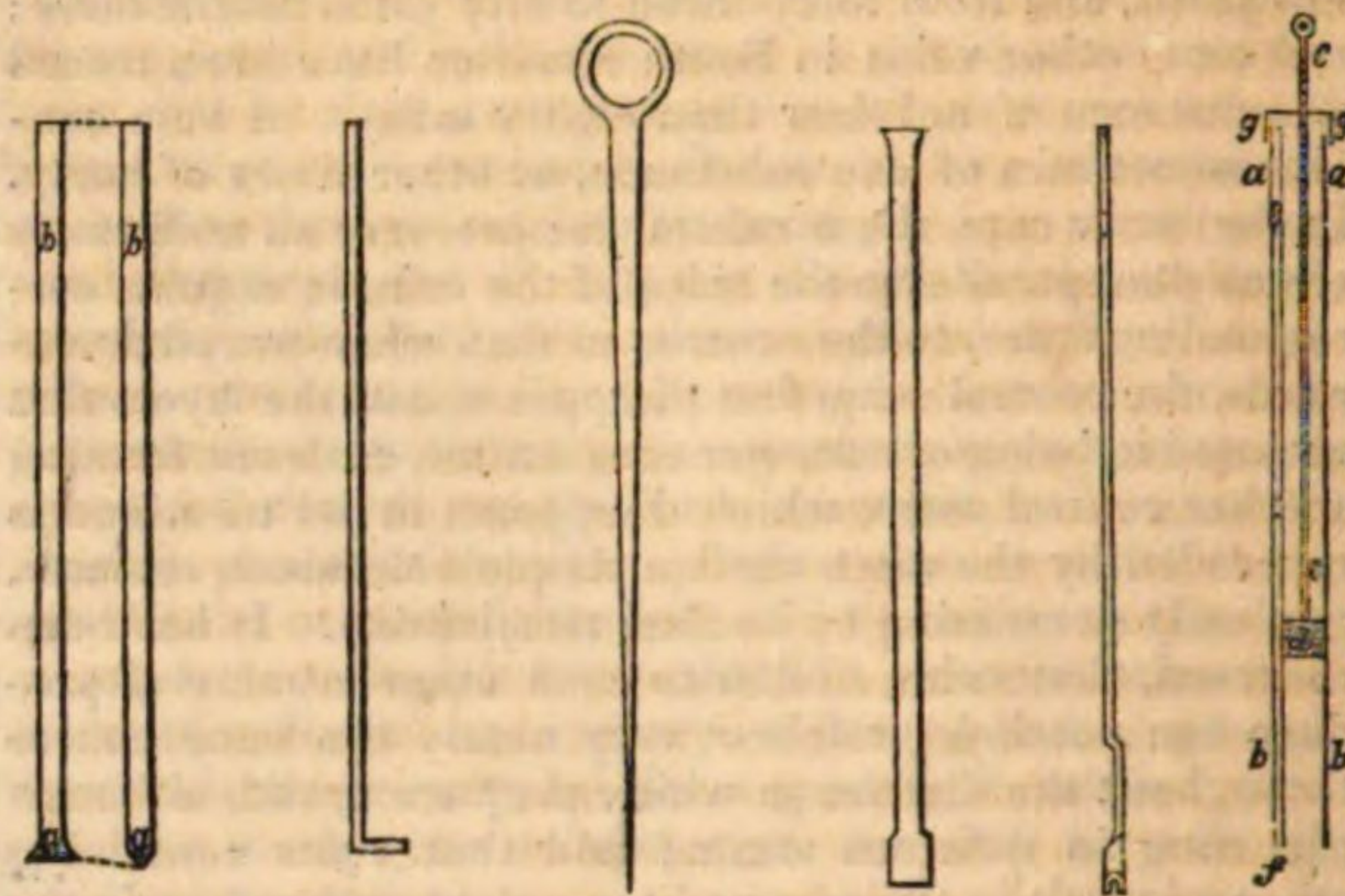
Porphyry consists of crystals of quartz or felspar in a cement of hornstone or claystone; it is not stratified, nor do any mineral beds occur in it; and its colour varies according to the nature of the basis, although red and black are the most common. It is so hard that the art of cutting it for sculpture is now lost; indeed modern tools make no impression on the surface, although huge columns, and many beautiful specimens of chiselling, remain to convince us that it was practised by the ancients in great perfection. Many metalliferous minerals are found in porphyry. The mines of Hungary are worked in enormous rents or fissures in this rock. Porphyry also appears in Cornwall, Sweden, France, Saxony, Carinthia, Hungary, Siberia, Abyssinia, and North and South America.¹

For details as to the mineral deposits contained in the other primitive rocks, the reader is referred to the article MINES, where, under the different heads, ample information will be found on this, as well as on various other matters connected with the present subject.

II. One of the most important operations of practical mining is that of blasting, of which we shall now proceed to give some account.

The first part of the process consists in preparing or boring the hole for the reception of gunpowder. This is effected with the sharpened bar and the borer, represented in fig. 1, the length and breadth of both being variable. The shaded portion *a*, which is the cutting part, is of tempered steel; and the upper part, which is held by the workman, consists of iron. In the western part of Cornwall, the borer is held in one hand and the hammer in the other, the operation being performed by one person; but in the central and eastern parts, one person usually holds the borer, whilst another applies the hammer or *mallet*. From the borer being kept constantly in motion, the hole is made of a circular form, its depth varying from eight inches to five feet, and its breadth from one to three inches. Water is poured into the hole if none issue from the rock, to facilitate the operation of the borer; and the abraded matter

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5. Fig. 6. Mining.



is withdrawn by the *scraper*, fig. 2. It is afterwards further cleaned with a piece of wood, called a *swab-stick*, one end of which is prepared for the purpose. When the hole is inclined, and intended to be deep, a long borer is used, which one man raises and lets fall, the operation being for the most part performed by the momentum acquired by the instrument in descending from the height to which it is raised. This is called "*jumping*." If the hole be dry and much inclined, the gunpowder is now poured into it, the quantity requisite being at first guessed; but after a few explosions, it is seen whether the proportion employed be a just one or not, that is, sufficient to fracture the rock without breaking it in pieces and scattering them to a distance. If the latter effect be produced, the quantity of powder is diminished; but if the rock be not fractured, it must be increased. As some of the gunpowder will adhere to the moist sides of the hole, this must be wiped down with the end of the swab-stick. If the *rush* be used to convey a spark to the charge, a piece of clay is laid upon it, and through both the needle is inserted until it reaches *nearly* to the bottom of the hole.

The *nail*, fig. 3, is a metallic rod gradually tapering to a point, and at the other end it is formed into a ring. It was formerly made entirely of iron; but latterly its pointed extremity has been made of copper, because, during its insertion or removal, the iron-pointed nail sometimes caused ignition, and thus led to fatal consequences. Next to the powder is put some dry substance, and then clay, upon which are put down and gently beaten with the *tamping* or *ramming bar*, fig. 4, pieces of some stony substance, which readily yields to the hammer without giving a spark, as roofing tile, soft slate, decomposing porphyry, friable granite, coal, or solid copper, which are all occasionally used. At first a little is put in and beaten firmly down; then a second small quantity, a third, a fourth, and so on until the hole be entirely filled. It is desirable that each layer should be very thin, as the confining power of the tamping is considered to be in proportion to the number of layers; but this must be understood within certain limits. The tamping bar is usually made of iron, the lower extremity being shod with copper or brass; Dr Paris found, however, that an alloy of eighty-six parts of copper and fourteen of tin proved the most durable. The next point is the removal of the nail, which is effected by striking it upwards, or by the use of a lever. The *rush* is then introduced into the hole left by the nail, the pith having been first removed and its place filled with fine gunpowder. When all this has been done, nothing remains but the application of the fire, which is communicated by the ignition of one end of a match, or a piece of coarse paper smeared with grease, the other end being placed in contact with the

¹ See Mining Review, No. V. p. 13, et seq.

Min. rush, and the slow combustion affording time for the escape of the workmen.

The ignition of the charge, however, is frequently effected by the train being contained in a rod of quills, or by the use of Bickford's patent safety-rods. When either of these is employed, it is placed in the hole before the introduction of the charge; and in these cases the nail is not required. The operation of tamping is in every respect conducted as before. The rod of quills is merely a tube of common goose-quills, the smaller end of one being inserted in the larger extremity of another, until the tube be of the length required, that is, equal to the hole bored in the rock. The gunpowder with which the tubes are filled should be bruised to dust, and packed very closely in the tube. It might be thought that the compression to which such tubes are exposed during the process of tamping would prevent their combustion; but this is not the case, for so strong are they, when properly filled, that even the pressure of a smith's vice would produce no such result. The patent safety-rod is a column of gunpowder enveloped in a series of hempen yarns twisted spirally round it, and perfectly flexible. It is about three eighths or one half of an inch in diameter, consumes slowly, and rarely becomes extinguished until it be entirely burnt. The expense of the quills and the safety-rods is nearly the same, that is, threepence per fathom in length.

The preceding remarks are intended to apply to an *inclined* perforation. But when the aperture is nearly horizontal, which is frequently the case, the introduction of the charge is somewhat more difficult. Some miners make a cartridge or tube of paper, which they cement with grease, and which, being filled with fine gunpowder, is pushed with the swab-stick to the further extremity of the hole; others charge with the *flukey*, which may be described as the half of a hollow cylinder divided in the line of its axis, and being attached to the end of an iron rod, fig. 5, resembles a carpenter's auger, or a marrow-spoon. The tamping is in all cases alike, and the train may be laid in either of the ways already mentioned.

But when the hole has been moistened by the infiltration of water, the operation is much more difficult, and is accomplished either by claying the hole, or by introducing the charge in a pitched bag or tin-plate cartridge. Claying consists in filling as much of the further extremity of the hole as the charge is intended to occupy, with stiff clay, impervious to water, or at least very nearly so. Through this clay a cylindrical bar, usually made of iron, is pushed nearly to the extremity of the perforation, in order to make a space for the reception of the charge, which is at once introduced, and then the hole is tamped and the train laid in the ordinary manner. This operation requires to be performed with great rapidity, because the clay not being quite impervious to water, may become saturated, and the charge moistened, so as not to ignite when the train is fired. The pitched bag, above mentioned, is made of canvass, and so covered with pitch as to be impenetrable to water; the tin-plate cartridge is simply a tin case in a cylindrical form. When the bag or cartridge is used the charge is placed in it, the train for its ignition being laid through a tin-plate tube about one fourth of an inch in diameter. This receptacle is placed in the further extremity of the hole, sometimes imbedded in clay, and is tamped in the usual manner. The pitched bag is preferred to the cartridge, because the one fits the hole more exactly, whilst the regular figure of the other retains round it a little air, which, in yielding to the compressing force, impedes the full effect of the explosion.

An apparatus, invented by Captain Chenhalls, of St Just, in the western part of Cornwall, and denominated the *shifting cartridge*, has been found useful in charging holes of small depth. Fig. 6 represents a section of this

instrument. It consists of a copper cylinder *a b*, two feet in length, and one inch in diameter, containing a moveable rod *c*, which is graduated in inches, and has affixed to its extremity a leaden plug *d*, whilst the cap *g* is made to take off, in order to allow, at any time, the removal of the rod, for cleaning the interior. The manner of using it has been thus described. Draw out the rod as many inches as you require it to deliver of gunpowder, then invert the instrument, fill it, and place a piece of moistened clay at the mouth of the cylinder; it is now to be inserted in the hole, when, by pressing down the sliding-rod, the whole charge is immediately delivered in a mass without any loss; but before the instrument is withdrawn, the rod should be several times rammed down smartly upon the gunpowder. In charging *back holes*, that is, holes nearly horizontal, the clay should be stuck upon the end of the plug *d* previously to the introduction of the powder into the cylinder. When quills are used for a fuze, it will be found advantageous to affix in the cylinder a smaller tube for their reception, as represented by *ef*. Much has been said as to the waste of gunpowder in mines in consequence of the ignorance or carelessness of the workmen; and there is probably some ground for censure in this respect. But, on the other hand, whilst it is difficult for any but a practical miner to say where a perforation can be advantageously made, so nothing but experiment can determine the quantity of gunpowder requisite for any given hole, and this must necessarily be left to the workmen.

It has been frequently asserted that sand is a good and efficient substitute for tamping, as commonly practised; and numerous experiments have been made to establish this point, but hitherto without any very satisfactory results. In many cases the sand has been blown out, whilst, in some instances, effective explosions have ensued. Further experiments are certainly required to set this important point at rest, by determining the circumstances upon which success or failure depend.

With respect to accidental or premature explosions, by far the larger portion of these either originate from the nail, or are produced in the course of the tamping process. Those which originate through the nail occur only when the rush is used, and although the number of accidents has been considerably diminished since it was pointed with copper, yet even this has not entirely prevented them. They are caused, first, by the nail being driven to the very bottom of the hole, and its there coming in contact with substances which by percussion generate a spark; secondly, the nail, during the tamping, is subject to concussion, which, in certain circumstances, will produce a similar effect; and, thirdly, the removal of the nail may occasion a like result, especially if, when introduced into the hole, it had been so forcibly driven to the bottom as to bend its point, for in this case the curved part will occasion considerable disturbance in the contents of the hole, and the danger will not be materially diminished by the circumstance of the nail being pointed with copper. But by putting a small piece of clay at the bottom of the hole, and by taking care not to force the nail against its lower extremity, the hazard arising from this cause may in a great measure be obviated. The dangers incident to the tamping process spring chiefly from the gunpowder adhering to the sides of the hole; so that, if a spark be struck out during the operation, it will communicate to these particles, and ignite the charge. Fire may be struck, first, by the contact of the tamping bar with such portions of the sides of the hole as are calculated to afford a spark from collision; secondly, by the action of this instrument upon portions of the tamping, when the bar is not shod with copper or brass; thirdly, by the friction of such substances in tamping, against similar bodies in the sides of the hole; and, fourthly, by the friction of various parts of the tamp-

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ing against one another. The precautions to be used against the occurrence of accidents of this kind are, first, removing carefully the adhering particles of gunpowder from the sides of the hole; secondly, the use of a tamping bar shod with a substance which does not readily strike fire; and, thirdly, care in selecting substances for tamping which do not readily afford sparks by impact upon one another. Notwithstanding the use of quills and safety-rods, explosions of this class sometimes occur, their causes being apparently beyond the reach of such contrivances. But of the fatal accidents which have occasionally happened, the greater part are attributable to the carelessness of the workmen, rather than to their ignorance. Many explosions have originated from want of caution in boring a charge which has not ignited owing to the train having somehow been extinguished. In such cases, the tamping is removed by the borer, and, from the indifference of habit, the workmen frequently take no more care than if they were forming, or "beating down," a new perforation.¹

III. Humboldt, speaking of the state of the mining art in Mexico, strongly censures the method of blasting by powder, as therein employed. The holes for the reception of the cartridges are, he thinks, generally too deep, and the miners are not sufficiently careful in diminishing the mass of rock intended to yield to explosion. A great waste of gunpowder is consequently occasioned. In the mine of Valenciana, powder to the amount of L.150,000 was consumed from 1794 to 1802; and the mines of New Spain annually require from 12,000 to 14,000 hundredweights. Humboldt thinks it probable that two thirds of this quantity is uselessly employed.

The timber-work is also, according to him, very carelessly performed, although it ought the more to engage the attention of the proprietors of mines, as wood is every year becoming scarcer on the table-land of Mexico. "The masonry employed in the shafts and levels,² and especially the walling with lime, deserves great praise. The arches are formed with great care; and in this respect the mines of Guanaxuato may stand a comparison with whatever is most perfect at Freyberg and Schemnitz. The shafts, and still more the galleries or levels, have generally the defect of being dug of too great dimensions, and of occasioning, by that means, exorbitant expenses. We find levels at Valenciana,³ executed with the view of making trial on a poor vein, of a height of twenty-six or twenty-nine feet. It is an erroneous opinion, that this great height facilitates the renovation of the air; the ventilation depends on the equilibrium and difference of temperature between two neighbouring columns of air. They also believe, equally without foundation, that, in order to discover the nature of a powerful vein, very large drifts are requisite, as if, in mineral veins of from six to eight fathoms in width, it were not better to cut from time to time small cross drifts, for the purpose of discovering whether the mass of the vein begins to grow richer. The absurd custom of cutting every level of such enormous dimensions prevents the proprietors from multiplying the means of trial, so indispensable for the preservation of a mine and the duration of the works. At Guanaxuato the breadth of the oblique shafts dug stairwise is from five to six fathoms; and the perpendicular shafts are generally three, four, or five fathoms in diameter. The enormous quantity of ores extracted from the mines, and the necessity of working in them the ropes attached to six or eight whims, necessarily occasion the shafts of Mexico to be made of greater dimensions than those of Germany; but the attempt which has been made at Bolaños, to separate by beams the ropes of the whims,

has sufficiently proved that the breadth of the shafts may be diminished without any danger of the ropes getting entangled in their oscillatory motion. It would in general be very useful to make use of kibbles instead of leathern bags suspended by ropes for the extraction of the ores.

"The greatest fault observable in the mines of New Spain, and which renders the working of them extremely expensive, is the want of communication between the different works. They resemble ill-constructed buildings, where, to pass from one adjoining room to another, we must go round the whole house. The mine of Valenciana is justly admired on account of its wealth, the magnificence of its walling, and the facility with which it is entered by spacious and commodious stairs; yet it exhibits only a union of small works irregularly conducted; they are as it were *cul de sacs*, and without any lateral communication. I mention this mine, not because it is more faulty than the others in the distribution of its labours, but because we might naturally suppose it to be better organized. As subterranean geometry had been entirely neglected in Mexico till the establishment of the School of Mines, there is no plan in existence of the works already executed. Two works in that labyrinth of cross levels and interior winzes may happen to be very near each other without its being possible to perceive it. Hence the impossibility of introducing, in the actual state of most of the mines of Mexico, the wheeling by means of barrows, and an economical disposition of the ore plats."

The same distinguished traveller has also animadverted on the defective machinery employed in working and draining the Mexican mines. "We have already spoken of the truly barbarous custom of drawing off the water from the deepest mines, not by means of pump apparatus, but by means of bags attached to ropes which roll on the cage of a whim. The same bags are used in drawing up the water and the ores; they rub against the walls of the shafts, and it is very expensive to keep them in repair. At the Real del Monte, for example, these bags only last seven or eight days; and they commonly cost five, and sometimes seven and eight shillings a piece. A bag full of water, suspended to the cage of a whim with eight horses (*malacate doble*), weighs 1250 pounds; it is made of two hides sewed together. The bags used for the whims called *simple*, those with four horses (*malacates sencillos*), are only half the size, and are made of one hide. In general the construction of the whims is extremely imperfect; the bad custom also prevails of forcing the horses, by which they are made to go at far too great a speed. I found this speed at the shafts of San Ramon, at Real del Monte, to be no less than ten feet and a half per second; at Guanaxuato, in the mine of Valenciana, from thirteen to fourteen feet; and everywhere else I found it more than eight feet. Don Salvado Sein, professor of natural philosophy at Mexico, has proved, in a very excellent paper on the rotatory motion of machines, that, notwithstanding the extreme lightness of the Mexican horses, they produce only the *maximum* of effect on the whims when, exerting a force of 175 pounds, they walk at a pace of from five to six feet in the second.

"It is to be hoped that pumps, moved either by horse-engines of a better construction, or by water-wheels, or by pressure-engines, will at last be introduced in the mines of New Spain. If wood, and coal, which has only yet been discovered in New Mexico, should be found sufficiently abundant for employing the steam-engine, the use of it would be of great advantage in the inundated mines of Bolaños, as well as in those of Rayas and Mellado.

"It is in the draining the mines of water that we particu-

Mining Review, No. VI. p. 249, et seq.

² Especially in the mines of Valenciana, Guanaxuato, and Real del Monte.

³ Canon de la Soledad.

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larly feel the indispensable necessity of having plans drawn up by subterranean surveyors (*géomètres*). Instead of stopping the course of the water, and bringing it by the shortest road to the shaft where the machines are placed, they frequently direct it to the bottom of the mine, to be afterwards drawn off at a great expense. In the district of mines of Guanaxuato, nearly two hundred and fifty workmen perished in the space of a few minutes, on the 14th of June 1780, because, not having measured the distance between the works of San Ramon and the old works of Santo Christo de Burgos, they had imprudently approached this last mine while carrying on a drift in that direction. The water, of which the works of Santo Christo were full, flowed with impetuosity through this new gallery of San Ramon into the mine of Valenciana. Many of the workmen perished from the sudden compression of the air, which, in taking vent, threw to great distances pieces of timber and large masses of rock. This accident would not have happened if, in regulating the operations, they could have consulted a plan of the mines." (A.)

MINNIN, a stringed instrument of music amongst the ancient Hebrews, having three or four chords to it. There is reason to question the antiquity of this instrument, both because it requires a hair bow, which was a kind of plectrum not known to the ancients, and because it so much resembles the modern viol. Kircher took the figures of this instrument, the machul, chinnor, and psaltery, from an old book in the Vatican library.

MINOR, a Latin term, literally denoting *less*, and used in opposition to *major*, greater.

MINOR, in *Law*, denotes a person under age, or one who, by the laws of the country, has not yet arrived at the power of administering his own affairs, or the possession of his estate.

MINOR, in *Logic*, is the second proposition of a formal or regular syllogism, called also the *assumption*.

MINOR, in *Music*, is applied to certain concords, which differ from or are lower than others of the same denomination, by a lesser semitone, or by four commas. Thus we say, a third minor, or lesser third, or a sixth major and minor. Concords which admit of major and minor, or greater and less, are said to be imperfect concords.

MINORCA, one of the Balearic Islands, in the Mediterranean Sea, now belonging to the crown of Spain. Its history is the same as that of the adjacent islands of the same group, till the year 1708, when, in the war of the Spanish succession, it was captured by a force consisting of a fleet of English ships, and a land army composed of English marines and some battalions of Spaniards, Italians, and Portuguese, which Count Staremhourg, the imperial general at Barcelona, had furnished to the English general Stanhope. To this force, after some short time, the garrison surrendered, and the inhabitants submitted to the English government. The peace of Utrecht in 1712 fixed the island in the hands of the possessors, with whom it continued till 1758. At the breaking out of that war, a French force landed at Minorca, and invested the citadel of St Philip, in which Blakeney with an insufficient army commanded. Admiral Byng with a fleet was despatched to his relief; but not having acted with the decision that was anticipated, and having withdrawn to refit at Gibraltar, Blakeney, after as gallant a defence as could be made, was compelled to surrender. The French retained their conquest till the year 1763, when, by the peace of Paris, it was again given up to the English. Soon after that cession, a great number of the natives were induced, by a body of speculators in England, to emigrate to the province of East Florida, which by the same treaty had been delivered up to Great Britain. The colony consisted of more than a thousand individuals, including females and children, who were indented to a Dr Turnbull, the agent of the company, and landed to the south

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of St Augustine, where they were employed in the cultivation of the land in the manner to which they had been accustomed. But discontents in a few years broke out, and some law proceedings at length dissolved the engagements, when the settlers removed to St Augustine, abandoning the establishment called New Smyrna, and found occupation in various ways. They have, however, multiplied so much in the sixty years since their emigration, that their descendants formed the mass of the population at the period when East Florida became one of the states of the North American Union.

Minorca was captured by the Spaniards in 1782, but in 1798 was again taken possession of by the British; and by the peace of Amiens in the year 1802 it was finally ceded to Spain, whose dominion over it has not since been disturbed.

This island is about thirty-eight miles from Majorca, and 120 from the coast of Spain. The exact position of the parade in George Town, near Port Mahon, as ascertained by a mean of several astronomical observations, is 39. 52. 55. north latitude, and 4. 20. east longitude from Greenwich. The whole extent is about 300 square miles. About one quarter of the land is cultivated, and about one half is pasture, the remainder being neglected and sterile. There are no woods, although abundance of myrtle shrubs grow in some parts, and are used for tanning leather, for brooms, and also for fuel. In the interior of the island there are a few small brooks only, and very few wells, many of which are brackish; and hence most of the houses are provided with cisterns for supplying the inhabitants with rain water. Both wheat and barley are grown, but not sufficient to feed the population; so that one third of the consumption is supplied by importation. On the other hand, fruits of all kinds are very abundant, especially melons, grapes, and oranges. The wine is plentiful, and both the red and the white are of excellent flavour and of great strength. The chief rural wealth, however, consists of the live stock. There are excellent breeds of asses of very large size and of great strength, and the mules arising from their crosses with horses are held in the highest estimation. There are said to be between 6000 and 7000 cows, from which cheese is made, that by some is preferred to the produce of Lodi in Italy. The sheep are stated to be 45,000, and the goats 5500; whilst the swine, fattened till they weigh from 450 to 500 pounds, are more than 10,000 in number.

The island is divided into four districts, called *terminos*, viz. Cittadella, Mercadel, Alayor, and Mahon. The inhabitants all adhere to the Catholic church with great zeal, and with not a little superstition. The number is estimated at 35,000. The fishing on the shores gives occupation to many; whilst some few are employed in obtaining marble, slate, and limestone, from the quarries. The climate is in general very healthy, being cooled in the summer by the breezes from the sea, and not being liable to frost or snow in the winter. The complexion and features of the natives are like those of Spain, but somewhat darker. The females marry at a very early age, so that by the time they reach twenty-five years, they become old women. It is not unusual to see females with children at the breast from eleven to twelve years of age.

The island is of moderate height as approached from the sea, and its surface then appears level, with one remarkable elevation towards the centre, called Mount Toro, having on its summit a convent dedicated to the blessed Virgin.

The most important circumstance relating to Minorca is the value capable of being derived from its excellent harbours of Port Mahon at the east end, Fornella on the north side, and Cittadella on the west, from the small but convenient coves around it, and from the good anchorage

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on its shores. The capital is Cittadella, and the other towns are Mahon and Fornella.

MINORS, or FRIARS MINOR, an appellation which the Franciscans assume, out of humility, calling themselves *fratres minores*, or lesser brothers, and sometimes *minorites*. There is also an order of regular minors at Naples, which was established in the year 1588, and confirmed by Pope Sixtus V.

MINOS, in fabulous history, a king of Crete, who was the son of Jupiter and Europa. He flourished about 1432 years before the Christian era, and gave laws to his subjects, which remained in force in the age of the philosopher Plato, about a thousand years after the death of the legislator. His justice and moderation procured him the appellation of the favourite of the gods, the confidant of Jupiter, and the wise legislator, in almost every city of Greece; and, according to the poets, he was after death rewarded for his equity with the office of supreme and absolute judge in the infernal regions. In this capacity he is represented sitting in the middle of the shades, and holding a sceptre in his hand. The dead plead their different causes before him; and the impartial judge shakes the fatal urn, which is filled with the destinies of mankind.

MINOTAUR, in fabulous history, was a celebrated monster, half man and half bull. The minotaur was the fruit of Pasiphaë's amour with a bull. Minos having refused to sacrifice a white bull to Neptune, an animal which he had received for that purpose from the god, this offended Neptune, and he made Pasiphaë, the wife of Minos, enamoured of the bull, which had been refused to his altars. Dædalus prostituted his talents in subserviency to the queen's unnatural desires, by which means Pasiphaë's horrible passions were gratified, and the Minotaur came into the world. Minos confined in the labyrinth this monster, which convinced the world of his wife's lasciviousness, and reflected disgrace upon his family. The Minotaur usually devoured the chosen young men and maidens whom the tyranny of Minos yearly exacted from the Athenians. Theseus delivered his country from this tribute, when it had fallen to his lot to be sacrificed to the voracity of the Minotaur; and by means of Ariadne, the king's daughter, he destroyed the monster, and made his escape from the intricacies of the labyrinth.

The fabulous tradition of the Minotaur, and of the infamous commerce of Pasiphaë, has often been explained. Some suppose that Pasiphaë was enamoured of one of her husband's courtiers called Taurus; and that Dædalus favoured the passions of the queen, by suffering his house to become the retreat of the two lovers. Pasiphaë some time afterwards brought forth twins, one of whom greatly resembled Minos, and the other Taurus; and in the natural resemblance of their countenance with that of their supposed fathers originated their name, and also the fable of the Minotaur.

MINSK, a province of the Russian empire, in Europe, extending in north latitude from 51. 12. to 55. 49. and in east longitude from 25. 13. to 30. 45. It is bounded on the north by Witepsk, on the east by Mohilew, on the south-east by Tschernigow, on the south by Kiew and Volhynia, on the west by Grodno, and on the north-west by Wilna. It contains 38,082 square miles, divided into ten circles, in which there are 109 cities and towns, and a great number of villages, hamlets, and lone farms. The number of dwellings is stated by Georgi at 148,219, and that of the inhabitants at 1,135,041. The towns are commonly both poor and filthy, being chiefly inhabited by Jews, who are the traders, distillers, and innkeepers. It is one of the extensive plains of Eastern Europe, on which a hill may here and there be seen, with some respectable rivers; in the north and east it is covered with woods, and in the south-west with extensive morasses. As the extent

is 38,082 square miles, the poverty of the soil may account for the thin population. It is watered by several small streams, which terminate either in the Dnieper and run to the Black Sea, or in the Düna and run to the Baltic. There is a canal uniting those rivers, which run in opposite directions. The principal exportable commodity is wood. The chief product for home consumption is rye, which barely suffices for the supply of the inhabitants. There is little trade, and this may be described as the poorest province of European Russia.

MINSK, a city, the capital of the province and of the circle of that name, in European Russia. It is 603 miles from St Petersburg, on the river Swislocz, and is the seat of a Greek and a Catholic bishop, and of the several departments of the provincial administration. The functionaries connected with these form the greater part of the inhabitants, who do not exceed 3000, all the traders amongst whom are Jews. Long. 27. 33. E. Lat. 53. 58. N.

MINSTER, a parish of the county of Kent, in the hundred of Ford and the lathe of Scray, forty-nine miles from London. The church was collegiate, supposed to have been part of a monastery founded by Sexburga, the wife of Ercombert, king of Kent, and eighteen stalls still remain in it. It is situated on the north side of the isle of Thanet. The population amounted in 1801 to 707, in 1811 to 824, in 1821 to 920, and in 1831 to 911.

MINSTER-IN-SHEPPY, a large parish in the county of Kent, in the hundred of Rinslow and lathe of St Augustine, sixty-eight miles from London. It comprehends the dock-yards and part of the town of Sheerness, and derives its name from a convent of nuns, said to have been founded by a Saxon lady in the year 700. The population amounted in 1801 to 5561, in 1811 to 7003, in 1821 to 8414, and in 1831 to 7983.

MINSTER (Saxon, *mynster* or *mynstre*) anciently signified the church of a monastery or convent.

MINSTREL, an ancient term applied equally to a singer and an instrumental performer.

The word *minstrel* is derived from the French *menestrier*, and was not in use in this country before the Norman conquest. It is remarkable that our old monkish historians do not use the words *citharædus*, *cantator*, or the like, to express a *minstrel* in Latin; but either *mimus*, *histrion*, *joculator*, or some other word which implies gesticulation. Hence it should seem that the minstrels set off their singing by mimicry or action, uniting the powers of melody, poetry, and dancing.

The Saxons as well as the ancient Danes had been accustomed to hold men of this profession in the highest reverence. Their skill was considered as something divine, their persons were deemed sacred, their attendance was solicited by kings, and they were everywhere loaded with honours and rewards. In short, poets and their art were held in that rude admiration which is ever shown by an ignorant people towards such as greatly excel them in intellectual accomplishments. When the Saxons were converted to Christianity, in proportion as letters prevailed amongst them, this rude admiration began to subside, and poets were no longer a peculiar class or profession. The poet and the minstrel became two persons. Poetry was cultivated by men of letters indiscriminately, and many of the most popular rhymes were composed amidst the leisure and retirement of monasteries. But the minstrels continued to be a distinct order of men, and obtained their livelihood by singing verses to the harp at the houses of the great. There they were hospitably and respectfully received, and retained many of the honours conferred upon their predecessors, the bards and the scalds. Although some of them only recited the compositions of others, many of them still composed songs themselves, and all of them could probably invent a few stanzas upon occasion. There

Minsk
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Minstrel.

Minstrel. is no doubt that most of the old heroic ballads were produced by this order of men. Although some of the larger metrical romances might come from the pen of the monks or others, yet the smaller narratives were probably composed by the minstrels who sung them. From the amazing variations which occur in different copies of these old pieces, it is evident that they made no scruple to alter one another's productions, and the reciter added or omitted whole stanzas, according to his own fancy or convenience.

In the early ages, as is hinted above, this profession was held in great reverence amongst the Saxon tribes, as well as amongst their Danish brethren. This appears from two remarkable facts in history, which show that the arts of music and song were equally admired amongst both nations, and that the privileges and honours conferred upon the professors of them were common to both; and it is well known that their customs, manners, and even language, were not in these times very dissimilar.

When Alfred the Great was desirous to learn the true situation of the Danish army which had invaded his realm, he assumed the dress and character of a minstrel, and, taking his harp, and only one attendant (for in the earliest times it was not unusual for a minstrel to have a servant to carry his harp), he went with the utmost security into the Danish camp. Although he could not but be known to be a Saxon, the character he had assumed procured him an hospitable reception; he was admitted to entertain the king at table, and staid amongst them long enough to contrive that assault which afterwards destroyed them. This was in the year 878.

About sixty years afterwards, a Danish king made use of the same disguise to explore the camp of King Athelstan. With his harp in his hand, and dressed like a minstrel, Anlaff king of the Danes went amongst the Saxon tents, and taking his stand near the king's pavilion, began to play, and was immediately admitted. There he entertained Athelstan and his lords with his singing and his music; and was at length dismissed with an honourable reward, although his songs must have discovered him to be a Dane. Athelstan was saved from the consequences of this stratagem by a soldier, who had observed Anlaff bury the money which had been given him, from some scruple of honour or motive of superstition. This occasioned a discovery.

From the uniform procedure of both these kings, it is evident that the same mode of entertainment prevailed amongst both nations, and that the minstrel was a privileged character amongst each. Even as late as the reign of Edward II. the minstrels were easily admitted into the royal presence, as appears from a passage in Stow, which also shows the splendour of their appearance.

"In the year 1316, Edward II. did solemnize his feast of Pentecost at Westminster, in the great hall; where, sitting royally at the table with his peers about him, there entered a woman adorned like a minstrel, sitting on a great horse trapped, as minstrels then used, who rode round about the tables, showing pastime; and at length came up to the king's table and laid before him a letter, and forthwith turning her horse, saluted every one, and departed." The subject of this letter was a remonstrance to the king against the favours heaped by him on his minions, to the neglect of his knights and faithful servants. The messenger was sent in a minstrel's habit, as that which would gain an easy admission, and was a woman concealed under that dress, probably to disarm the king's resentment; for we do not find that any of the real minstrels were of the female sex, and therefore conclude this was only an artful contrivance peculiar to that occasion.

In the fourth year of Richard II. John of Gaunt erected at Tetbury in Staffordshire, a court of minstrels, with a full power to receive suit and service from the men of that pro-

fession within five neighbouring counties, to enact laws, and determine their controversies; and to apprehend and arrest such of them as should refuse to appear at the said court, annually held on the 16th of August. For this they had a charter, by which they were empowered to appoint a king of the minstrels, with four officers, to preside over them. These were every year elected with great ceremony; the whole form of which is described by Dr Plott, in whose time, however, they seem to have become mere musicians.

Even so late as the reign of King Henry VIII. the reciters of verses or moral speeches learned by heart intruded without ceremony into all companies, not only in taverns, but in the houses of the nobility themselves. This we learn from Erasmus, whose argument led him only to describe a species of these men who did not sing their compositions; but without doubt the others who did so enjoyed the same privileges.

We find that the minstrels continued down to the reign of Elizabeth, in whose time they had lost much of their dignity, and were sinking into contempt and neglect. Yet still they sustained a character far superior to any thing we can conceive at present of the singers of old ballads.

When Queen Elizabeth was entertained at Killingworth or Kenilworth Castle by the Earl of Leicester in 1575, amongst the many devices and pageants which were exhibited for her entertainment, one of the personages introduced was that of an ancient minstrel, whose appearance and dress are so minutely described by a writer there present, and give us so distinct an idea of the character, that we shall quote the passage at large.

"A person very meet seemed he for the purpose, of a xlv. years old, apparelled partly as he would himself. His cap off; his head seemingly rounded tonsterwise; fair kembed, that, with a sponge daintly dipt in a little capon's grease, was finely smoothed, to make it shine like a mallard's wing. His beard snugly shaven; and yet his shirt after the new trink, with ruffs fair starched, sleeked, and glistening like a pair of new shoes, marshalled in good order with a setting stick, and strut, 'that' every ruff stood up like a wafer. A side [*i. e.* long] gown of Kendale green, after the freshness of the year now, gathered at the neck with a narrow gorget, fastened afore with a white clasp and a keeper close up to the chin; but easily, for heat, to undo when he list. Seemingly begirt in a red caddis girdle: from that a pair of capped Sheffield knives hanging a' two sides. Out of his bosom drawn from a lappet of his napkin edged with a blue lace, and marked with a D for Damian; for he was but a bachelor yet.

"His gown had side [*i. e.* long] sleeves down to midleg, slit from the shoulder to the hand, and lined with white cotton. His doublet sleeves of black worsted: upon them a pair of points of tawny chamlet laced along the wrist with blue threaden pointes. A wealt towards the hands, of fustian-a-napes. A pair of red neather stocks. A pair of pumps on his feet, with a cross cut at his toes for corns; not new indeed, yet cleanly blackt with soot, and shining as a shoing horn.

"About his neck a red ribband suitable to his girdle. His harp in good grace dependent before him. His wrest tyed to a green lace, and hanging by: under the gorget of his gown a fair flaggon chain silver, as a Squire Minstrel of Middlesex, that travelled the country this summer season, unto fair and worshipful men's houses. From his chain hung a scutcheon, with metal and colour, resplendent upon his breast, of the ancient arms of Islington."

This minstrel, the author tells us, "after three lowly courtesies, cleared his voice with a hem....and wiped his lips with the hollow of his hand, for filing his napkin; tempered a string or two with his wrist; and, after a little warbling on his harp for a prelude, came forth with a so-

Mint
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Mirabeau.

lemn song, warranted for story out of King Arthur's acts."

Towards the end of the sixteenth century, this class of men had lost all credit, and were sunk so low in the public opinion, that in the thirty-ninth year of Elizabeth a statute was passed, by which "minstrels," wandering abroad, were included amongst "rogues, vagabonds, and sturdy beggars," and were adjudged to be punished as such.

MINT, the place or establishment in which the king's money is coined. See COINING.

MINTURNÆ, a town of Campania, between Sinuessa and Formiæ. It was in the marshes in this neighbourhood that Marius concealed himself in the mud, to avoid the partizans of Sylla. The people condemned him to death; but when the sound of his imperious voice had terrified the executioner, they showed themselves compassionate, and favoured his escape.

MINUET, a very graceful kind of dance, consisting of a coupee, a high step, and a balance. It begins with a beat, and its motion is triple.

The invention of the minuet seems to be generally ascribed to the French, and particularly to the inhabitants of the province of Poitou. The word is said by Ménage and Furetière to be derived from the French *menue* or *menu*, small or little, and in strictness to signify a small space. The melody of this dance consists of two strains, which, from being repeated, are called *reprises*, each having eight or more bars, but never an odd number. The measure consists of three crotchets in a bar, and is thus marked $\frac{3}{4}$, though it is commonly performed in the time $\frac{3}{8}$. Walther speaks of a minuet in Lully's opera of *Roland*, each strain of which contains ten bars, the sectional number being 5; a circumstance which renders it very difficult to be danced.

MINUTE, in *Geometry*, is the sixtieth part of a degree of a circle.

MINUTE of Time is the sixtieth part of an hour.

MINUTE, in *Architecture*, usually denotes the sixtieth, and sometimes the thirtieth, part of a module.

MINUTE is also used for a short memoir, or sketch of a thing taken in writing.

MINYÆ, a name given to the inhabitants of Orchomenos, in Bœotia, from Minyas, king of the country. Orchomenos the son of Minyas gave his name to the capital of the country; and the inhabitants retained their original appellation, in contradistinction to the Orchomenians of Arcadia. A colony of Orchomenians passed into Thessaly and settled in Iolchos; and from this circumstance the people of the place, particularly the Argonauts, were called *Minyæ*. This name they received, according to the opinion of some, not because a number of Orchomenians had settled amongst them, but because the chief and noblest of them were descended from the daughters of Minyas. Part of the Orchomenians accompanied the sons of Codrus when the latter migrated to Ionia. The descendants of the Argonauts, as well as the Argonauts themselves, received the name of *Minyæ*. They first inhabited Lemnos, where they were born of Lemnian women, who had murdered their husbands. But being driven from Lemnos by the Pelasgi, about 1160 before the Christian era, they came to settle in Laconia, and thence passed into Calliste with a colony of Lacedæmonians.

MIQUELETES, a name given to the Spaniards who inhabit the Pyrennean Mountains, on the frontiers of Aragon and Catalonia, and subsist by robbing.

MIRABEAU, VICTOR RIQUETTI, MARQUIS DE, one of the most eminent propagators of the doctrines of the French Economists in France, was born at Perthuis on the 5th of October 1715. He was the eldest surviving male descendant of a family esteemed ancient and noble even in Provence, and established there for above five centuries. This was the family of Riquetti or Arrighetti, which, hav-

ing been banished from Florence during the civil commotions which agitated that republic, settled in Provence, and there maintained themselves in the rank of the most noble families of the country. The most famous of them all was Riquetti, the author and engineer of the Languedoc Canal; but the relationship was denied by the preposterous and barbarous pride of the clan. The subject of this notice, like most of the elder branches of French noble families, was placed betimes in the army; he was made a Chevalier de Malte at three years of age, an ensign at fourteen, and soon afterwards a captain; he served with credit and distinction at the sieges of Kehl and Philipsburg, and at the battles of Dettingen and Clusen; and, in the year 1743, he received the cross of St Louis, being then in the twenty-eighth year of his age. The death of his father having some years before placed him in a state of independence, he now quitted the army, and married the Marquise de Saulvebeuf, who, having been betrothed at twelve years of age, had been left a widow before she became a wife. But this marriage did not in the end prove fortunate. The lady was young, rich, and noble, but she was not handsome; and although her virtue was beyond all suspicion, the marquis, not satisfied with this, quarrelled with her, after she had lived with him fifteen years in peace and comfort, and had borne him eleven children; took into his house a fascinating young Swiss lady called Madame de Pailly; lived openly with the latter as his mistress; turned his unfortunate wife out of doors; and then engaged in a course of litigation with her, and of cruel as well as treacherous processes against her, which rendered both wretched, and made them the subject of universal talk, the objects of general censure, without profiting any human being except Madame de Pailly, the lawyers, and the retailers of scandalous gossip in the drawing-rooms of Paris.

The chief object of the Marquis de Mirabeau in quitting the profession of arms was to lead a life of literary retirement, and to improve the condition of his rural dependents. Towards the latter, indeed, his conduct seems to have been uniformly sensible, just, and kind; he was their real father, and they were in fact the only children who ever found in him the virtues of the paternal character. He went to reside in the family chateau in Provence; but neither the distance from Paris nor the state of the country suited his spirit or agreed with his taste. Accordingly, he purchased the estate of Bignon, fifteen miles from Sens and Nemours, and soon afterwards an hotel in Paris. He then entered upon the career of philosophy, which he pursued for half a century, and which terminated only with his life, about the beginning of the French Revolution, when he left the world with a reputation for virtue greatly exaggerated, and for talents much below his real merit. He died at Argenteuil on the 13th of July 1789, at a time when his son, the Count de Mirabeau, was rapidly rising to a supremacy of influence and power in the National Assembly.

The Marquis de Mirabeau was, after Quesnay, the chief patriarch of the sect of Economists; and was also well known and distinguished for his practical attention to economics as a considerable landowner and a patrician of high rank. But his style, which had the faults common to all the writers of the sect, was, besides, uncouth and fantastical in a remarkable degree, being deformed by an unhappy affectation of imitating the manner of Montaigne in an accumulation of trivial redundancies, which he called "his dear native exuberance," as well as by a certain false heat, and an incredible excess of pride and of dogmatism. That these defects, however, were not the result of any natural cloudiness or obliquity of mind, but of the vicious standard upon which he had formed his taste, is evident from his correspondence published in the Bio-

Mirabeau.

Mirabeau. graphical Memoirs of his son.¹ Indeed his letters form, in all respects, a perfect contrast to his more elaborate compositions, being as remarkable for their natural grace, idiomatic elegance, and perfect perspicuity, as the latter are for their rugged dulness, their pedantic extravagance, and their affected obscurity. Nothing, in truth, can be more entirely unlike than the philosopher and the man; the enlightened economist and the haughty aristocratic noble; the friend of Quesnay and the father of Mirabeau; the *Ami des Hommes* and the *Père de Famille*.

But all this is by no means without example. Such discrepancies between the public and the domestic characters of men are indeed far from being of rare occurrence. The difference here, however, is unfortunately carried farther than in almost any other instance known. The characteristic of the sect to which the Marquis belonged was a rigorous love of the strictest justice; but his treatment of his son exhibits one perpetual scene of all justice grossly outraged. To observe moderation, to regard the useful end of all things, to act as if they were born not for themselves but for all mankind, were the leading maxims of the Economists:

Secta fuit, servare modum finemque tenere,
Naturamque sequi, patriæque impendere vitam;
Nec sibi, sed toti genitum se credere mundo.

The predominant passion of the marquis, however, was family pride; moderation neither in this nor in any other feeling was never for an instant the inmate of his mind nor the regulator of his thoughts; he always spoke, wrote, and acted in private life, as one who never doubted that the world was made for the *order*, not the *sect*, to which he belonged, and that his first and highest duty was to keep the Mirabeau family at the head of the privileged class. To follow the dictates of nature, and devote their lives to the cause of truth, were precepts constantly inculcated by the Economists. The most inveterate prepossession against his first-born; the most refined cruelty of treatment which his ingenuity could devise for that child; even the expedient of leaving him in wretched circumstances, and restoring him to liberty, that he might either terminate his existence in despair or forfeit his life to the law; accompanied with an adulterous connection formed under his own roof, and which drove from his house a wife who had borne him eleven children, and brought an accession to his income of L.2000 a year;—such, not to mention imputed iniquities of a still darker complexion, are the traits of private character which distinguished the lover of nature and of truth, and which, in the work already referred to, are, for the most part, represented under the infallible testimony of his own hand. To the same authority we are further indebted for proofs of a difference still more marvellous, and of which there is probably no other example. The author of the dullest, and most heavy, uninteresting books, written in the most tiresome, insipid, and almost intolerable style, is the author of the very best, most lively, and most entertaining letters we have ever met with, written in a style which, for originality, raciness, force, and felicity of diction, is almost without a rival. “Les lettres familières,” says the editor of the *Mémoires Biographiques*, “que nous avons par milliers, et qui furent toujours remarquables par un naturel abondant et facile, par une aisance spirituelle et gaie, forment le plus inexplicable des contrastes avec ses écrits destinés à la publicité, tracés pour ainsi dire en sa présence, et dans lesquels le fond toujours très-sensé des idées, est décrié par la couleur particulière de son style obscur, pesant, et baroque, mélangé de tropes bizarres, d’incohé-

rentes métaphores, en un mot, il faut le dire, de galimatias intolérable.”

The works of the Marquis of Mirabeau, which have been called the Apocalypse of Political Economy, form no less than twenty-two volumes; but those alone which are now known or consulted are *L'Ami des Hommes*, *Théorie de l'Impôt*, *Philosophie Rurale*, and *Education Civile d'un Prince*. Besides these, he contributed a vast number of papers to the *Journal d'Agriculture* and the *Ephémérides du Citoyen*, the former of which reached thirty, and the latter forty volumes. The greater part of his works have been collected and published as a sequel to the *Ami des Hommes*, in eight vols. 12mo, or three vols. 4to. Of these, the following is nearly a complete list, viz. *Ami des Hommes*, Paris, 1755, in five vols. 12mo; 2. *Examen des Poésies sacrées de Lefranc de Pompignan*, 1755, in 12mo; 3. *Mémoire sur les Etats Provinciaux*, 1757, in 12mo; 4. *Mémoire concernant l'Utilité des Etats Provinciaux*, 1757, in 8vo; 5. *Réponse du Correspondant à son Banquier*, 1759, in 4to; 6. *Théorie de l'Impôt*, Paris, 1760, in 4to and 12mo; 7. *Philosophie Rurale, ou Economie Générale et Particulière, de l'Agriculture*, Amsterdam, 1764, in three vols. 12mo; 8. *Lettres sur le Commerce des Grains*, 1768, in 12mo; 9. *Les Economiques*, Paris, 1769, in two vols. 4to, or four vols. 12mo; 10. *Lettres Economiques*, Amsterdam, 1770, in 12mo; 11. *Les Devoirs*, Milan, 1770, in 8vo; 12. *La Science, ou les Droits et les Devoirs de l'Homme*, Lausanne, 1774, in 12mo; 13. *Lettres sur la Législation, ou l'Ordre Légal dépravé, rétabli et perpétué*, Berne, 1775, in three vols. 12mo; 14. *Entretiens d'un jeune Prince avec son Gouverneur*, Paris, 1785, in four vols. 12mo; 15. *Education Civile d'un Prince*, Dourlac, 1788, in 8vo; 16. *Hommes à célébrer pour avoir bien mérité de leur Siècle et de l'Humanité par leurs écrits sur l'Economie Politique*; 17. *Rêve d'un Goutteux*, 1788, in 8vo. In his eulogium of Quesnay, inserted in the *Ephémérides du Citoyen*, he styles the head of the sect of the Economists *Maître de la Science*, and places him above both Socrates and Confucius; and this piece is still sought for as a model of the perplexed and nonsensical style of writing (*style amphigourique*). (A.)

MIRABEAU, HONORE-GABRIEL RIQUETTI, COMTE DE, famous for the influence, or rather ascendancy, which he exercised over the French Revolution, was son of the preceding, and was born at Bignon, near Nemours, on the 9th of March 1749. He was endowed by nature with a robust constitution, a quick and vigorous understanding, a lively imagination, passions more vehement than are almost ever found in union with such intellectual powers, and a disposition kindly and humane. His temperament led to the early development both of his bodily and mental faculties; and there are few instances on record of children forming such manly ideas as he appears to have entertained, even during his infancy. The peculiar circumstances in which he was placed, from his boyhood upwards, by the singular opinions, strange prejudices, and unfeeling temper of his father, exercised a powerful influence upon his whole conduct, and must, in every material respect, have deeply affected his character. Yet we may appreciate his merits and faults even through the artificial covering which was thus thrown over his nature; and although impetuosity of feeling, and a corresponding disregard of the obstacles which he should have respected instead of overleaping, form a predominant feature of his mind and habits, we cannot fairly charge him with those faults which go mainly to form the vicious disposition.

His youth was confided to an able preceptor, the elder

¹ *Mémoires Biographiques, Littéraires, et Politiques de Mirabeau*; écrits par Lui-même, par son Père, son Oncle, et son Fils Adoptif. Paris, 1834, in five vols. 8vo. See also *Edinburgh Review*, vol. lxii. p. 186, et seq.

Mirabeau. Lachabeaussière; but this meritorious individual, being thwarted in his plan, could not turn to advantage the ardour which devoured his pupil. The latter came out of his hands with a slight knowledge of Latin and of the classics, and was at length thrown into a military boarding-house, where he skimmed the surface of different languages, as well as that of the elegant arts, and was initiated into the mathematics by the celebrated Lagrange. He appears to have been early seized with the desire of writing; for whilst his head was only filled with scattered and isolated notions, he yielded to this impulse, and published an eloge of the great Condé, as well as some pieces in verse.

At the age of seventeen he entered the cavalry as a volunteer; and, disregarding the ridicule to which those officers exposed themselves who sought to dignify the futile indolence of a garrison life by some useful employment, he read all the works he could procure on the military art. These studious habits, even if they had not been prompted by an insatiable desire of knowledge, would have been rendered necessary by the parsimony of a selfish and haughty father, who, discovering with pain in the heir of his name, a spirit of independence, incapable of bending to the paternal yoke, adopted a cruel system of checking his prodigious activity by means of pecuniary embarrassments. But the niggardly treatment to which his comfort and respectability were all his life sacrificed, and which his father sought to reconcile with a family pride almost without parallel, never made the son forget who and what he was, by descending to any flagrant act of meanness or dishonour; and whilst pressed by the want of the common necessities of life, and tortured by the sight of those whom he most loved suffering the same privations, his exertions to relieve himself were always confined to the work of honest though obscure industry; nor has any one of his innumerable enemies, domestic, personal, or political, ever charged him with using, for the purpose of solicitation, that pen which soon became his only resource against want.

About this time a love adventure in which the young count engaged made a great noise; and in virtue of a *lettre de cachet*, solicited by his father, he was sent prisoner to the Isle of Rhé. The *Ami des Hommes* even entertained the notion of cutting off his son from society, by banishing him to the Dutch-American colonies; and it was only by the most pressing representations that the philosophical marquis was induced to abandon the humane project of sending his son to perish under the tropical heats and rains of Surinam. At length the count obtained permission to make the campaign of Corsica, and there served with such distinction that paternal pride was for a moment soothed; but when, recompensed with a brevet as captain of dragoons, he solicited his father to purchase him a regiment, he received this strange reply, "That the Bayards and the Duguesclins had not proceeded thus." After the submission of Corsica, the Count de Mirabeau took up his pen to draw a picture of the oppression which Genoa had exercised over that country. This work had, no doubt, many imperfections; yet, defective as it was, it bore the impress of talent, and, although it displeased the Marquis de Mirabeau, the states of Corsica thought it of sufficient importance to deserve being printed. On his return to France, he succeeded in ingratiating himself with the Friend of Men, and, to please the philanthropist, consented to bury himself for some time in the Limousin, where he occupied himself with improving the lands, and settling some litigations. But, growing weary of these obscure labours, he repaired to Paris in 1771, and perceived that his short-lived favour was about to expire. It was then that he said to the Marquis of Mirabeau, "Mais, mon père, quand vous n'auriez que de l'amour-propre, mes succès seraient encore les vôtres." His contempt for the empiricism of the Economists, and the manifest opposition which he showed

to the despotism of such men as Maupeou and Terray, completed his disfavour with the *Ami des Hommes*, who, notwithstanding his aristocratic pride, had been always accustomed to cringe to authority.

In the same year he went to Provence, ostensibly to look after the family estates, but probably to domesticate himself amongst the people of that country, and also to raise up there enemies to the new parliament. In 1772, he married Marie-Emilie de Covet, only daughter of the Marquis de Marignane, a young and rich heiress, but whose fortune consisted almost wholly in substitutions and successions, which could not be available until they opened in the ordinary course of events. He received from his father-in-law a pension of 3000 francs, and from his own father an allowance of 6000, being about L.360 in all; but before the lapse of two years he had squandered away the double of all his disposable means, and involved himself in difficulties. Arrangements might easily have been made with his creditors; but the stern patron of the Economists preferred to lay his son under interdict, and confine him by order of the king to Manosque, a small borough on his property. It was in this seclusion that, warmed by the perusal of Tacitus and Rousseau, Mirabeau wrote in haste, under the impulse of the moment, his *Essai sur le Despotisme* (published in Holland in 1776); a piece full of fire and rough vigour, but, as a whole, perhaps the most incoherent of all his productions. The old marquis, dreaming only of formulas, and slavish in his adulation of authority, could scarcely be expected to relish the bold heresies of his son; and, unhappily, the latter was soon guilty of another, and, as it was deemed, still graver transgression.

Having broken his ban for the purpose of challenging some genteel poltroon who had insulted one of his sisters, but who, when called to account, refused to fight, a new proceeding was in consequence directed against him, and his father succeeded in having him detained in the castle of If, whence he was transferred to Fort Joux, in the year 1776. But here, as at the Isle of Rhé, he charmed and conquered all who came near him. By the magic of his language and manners he completely subjugated the governor, and in consequence succeeded in having the adjacent town of Pontarlier included within the limits of his prison. It was during his stay there that he first saw Sophie de Ruffey, a young and amiable girl of about eighteen, whom her parents had married to a husband considerably above seventy, the Marquis de Monnier, ex-president of the chamber of accounts at Dole. Inflamed with the most violent love, he soon succeeded in seducing a young and credulous woman; and this affair immediately involved him in fresh troubles. The family of the outraged husband, that of Madame de Monnier, and his own, combined together, although with opposite intentions, to call down upon his head all the rigour of the law. At this time Malesherbes wrote to him in these terms: "I am quitting the ministry, and the last counsel I can give you is to fly, and take foreign service." Mirabeau acted on this advice, and Sophie proceeded to rejoin him in Switzerland, whence they took refuge in Holland.

The conduct of Mirabeau in this affair, though it cannot be defended, admits of some palliation; and it would have been well if the influence of disorderly passions had not plunged him into other and still more culpable excesses. A girl of eighteen married to a man of seventy-five, and only nominally married to this keeper, alternately confiding and jealous, now tempting her by indulgence and carelessness, now watching and restraining with tormenting and suspicious rigour; these were the circumstances which first awakened in Mirabeau's bosom the most irresistible of the passions, and which is only the more dangerous by so often assuming the garb, and uniting itself with the reality, of virtuous propensities. The elopement which fol-

Mirabeau. lowed, and which was caused by a dislike on both parts to play the hypocrite, and live with the man whom they were deceiving, proved altogether alien to the habits of French society, and grievously outraged the feelings of those refined profligates, who, reckoning vice itself nothing, held indecorum to be the worst of all enormities; who preferred the semblance to the reality of virtue, and forgave one offence if the more debasing crimes of falsehood and hypocrisy were added to veil it from the public view. An outcry was accordingly raised throughout all society in France, and even re-echoed in Europe, against the unheard-of enormity. A young woman had left her superannuated husband, whom she had, by the customs of society, been compelled to take as her tyrant and tormentor under that name; and had left him for one of an age near her own, who sacrificed himself for her deliverance. They had rebelled against those rules which regulated the vicious intercourse of nobles in France; they had outraged all the habitual feelings of patrician nature, by refusing to lead a life of pretence, and treachery, and secret indulgence; they had even brought into jeopardy the long-established security of illicit intercourse, understood without being avowed; and the veil was thus about to be torn away from all those endearing immoralities which gave occupation and interest to high life, and broke the monotony of an existence which demanded that it should never be ruffled, except by voluntary excitements. Hence all society, that is, all the upper and worthless portion of it, united against the hapless pair. Mirabeau was regarded as a monster; and the conduct of his father, who hunted him over all Europe, and then immured him in a dungeon during the best years of his life, was excused by all, and censured by none; whilst nobody ever thought of visiting with the slightest blame, none ever ventured "to hint a doubt or hesitate dislike" of that very father, who had turned his wife, the mother of his children, out of doors, and had installed an unprincipled strumpet in her room.¹

He had no sooner fled than the parliament of Besançon charged him with abduction and robbery, condemned him in contumacious absence, and caused him to be decapitated in effigy; a proceeding equally ridiculous in itself, and illustrative of the manners and morals of the time. Meanwhile, the count put himself in the pay of the Dutch booksellers, and sought, by indefatigable labour, to provide resources for himself and his companion. During some eight months, he toiled hard, doing endless Gibeonite work, but commonly earning his gold louis a day. The most considerable task he had to perform was the translation of Watson's *History of Philip II.*, which he undertook along with one Durival. At this time, having learned that his father accused him of having dishonoured his bed, Mirabeau made cruel reprisals on his unrelenting parent, by disseminating libels in which the marquis was accused of the most shocking crimes and enormities. Finding his means of subsistence inadequate, he contemplated emigrating to America; but he was not allowed time to carry this project into effect. On the 14th of May 1777, he was seized by Brugnière, an inspector of the French police, at Amsterdam, in virtue of an order from the king, which had been sanctioned by the Dutch government; and, along with Sophie, then pregnant, he was carried to Paris, where he was immured in the fortress of Vincennes, and his mistress placed in a *maison de surveillance*.

In this prison Mirabeau underwent a detention of forty-two months. At first he was allowed neither books nor writing materials; and when at length this indulgence was granted him, he was only permitted to correspond with Madame de Monnier, on the condition that his letters should be seen by the governor, Lenoir (whose affections he had,

as usual, entirely gained), and afterwards returned to this keeping. This correspondence lay forgotten in Lenoir's desk until the year 1792, when it was taken away by Manuel, the procureur of the commune, and by him given to the world on a speculation of profiting by the sale. It would have been well if these letters had never seen the light, and been buried in the gulf of oblivion; and much more does the same observation apply to some of the other writings which were the works of his hours of confinement in Vincennes, particularly to a *Biblion Eroticon*, and a romance entitled *Ma Conversion*, both shameful and flagitious productions, the subsequent publication of which leaves a deep stain on the memory of Mirabeau. Indeed, one of the darkest parts of his conduct relates, not so much to Madame de Monnier, as to *Sophie*. When, under that name, he dragged her before the public, and indulged a loose and prurient fancy in catering to the worst appetites of licentious minds, he became justly the object of aversion and disgust; he ranged himself with the base manufacturers of obscene works, and even took precedence of these in profligacy by making his own amours the theme of his abandoned contemplations. This is the very worst passage in his history, because it is one which admits neither defence nor palliation. It is nothing to the purpose that these flagitious writings *may* have been afterwards used from necessity. If that was the cause of giving such shameful effusions publicity, it may well be said that the offence of the composition, disgusting as it was, merits the least grave portion of the blame. "Mirabeau's correspondence with Madame de Monnier, from his prison at Vincennes," says Dumont, "evinced more of sensuality than sentiment. Many of his letters are so repugnant to modesty, that they degrade the person to whom they are addressed; for no man would presume to adopt so licentious a style in writing to a woman for whom he had the least esteem."² Yet, strange as it may seem, much of this obscenity was borrowed from the licentious novels and periodicals of the day; and even the *Mercure de France* was put in requisition, when it afforded any thing suited to the purpose of the writer.

At length, after an imprisonment of three years and a half, Mirabeau was restored to society and to active life; with impaired strength indeed, but with undiminished energy of mind. On his liberation, he had an interview with Madame de Monnier, his Sophie, who had been supposed faithless, and he accordingly charged her with the offence; but she defended her conduct, and recriminated upon her lover, who, it may be presumed, could not so easily repel the accusation. They parted in mutual displeasure, and the estrangement was unhappily eternal. Of the voluntary death which she afterwards sought, and which has been repeatedly attributed to Mirabeau, every circumstance conspires to show that he was entirely innocent. Another accusation which, although often repeated, appears to be equally groundless, is, that about this time he sought to gain the favour of his father, by writing memoirs injurious to his mother, who, amidst all the wrongs she suffered from his family, had never been wanting in tenderness to him. There is something so unnatural and revolting in such an imputation, that, in the absence of all direct or sufficient evidence, it cannot for a moment be entertained; and, besides, with all his faults and his vices, which the malignity of party has not failed to exaggerate to the utmost, there was in his nature so large a fund of generosity and affection, as to render such conduct upon his part in the highest degree improbable.

There was one subject, however, which Mirabeau had much at heart, namely, to obtain the reversal of the de-

¹ Edinburgh Review, vol. lxii. pp. 196, 197.

² Dumont, *Souvenirs de Mirabeau*.

Mirabeau. cree which had condemned him to lose his head. With this view he constituted himself a prisoner at Pontarlier, in order to purge the sentence by contumacy, which had been pronounced against him; and there he produced in his defence those memoirs or pleadings which terrified his adversaries, who made vain attempts to obtain their suppression. In these productions it is easy to recognise the talent of a great orator, and to discover indications of that power which afterwards secured him an undisputed supremacy in the States-general and in the National Assembly. Of one of them, which he called his philippic, Mirabeau himself observed, "If this is not eloquence unknown to our barbarous age, I know not wherein consists that rare and seducing gift of heaven." His efforts were crowned with complete success. He dictated the law for Sophie as well as for himself; by a transaction between M. de Monnier and him, all the proceedings were annulled; and his adversary paid the expense.

Having effected this object, he proceeded to Provence, there to attempt another still more important; which was, to re-unite himself with his wife, and thus recover an income of about L.250 a year. He neglected nothing which could contribute to his success; mediations, prayers, affectionate entreaties: the lady was moved by his earnestness; but, yielding to the wishes of her family, she refused to resume the chains which had so deeply galled her. Mirabeau then appealed to the tribunals, employed all his eloquence in urging his claim, and drew a most flattering picture of his wife, whom he described as an angel of gentleness and goodness. The answer to this consisted in narrating his youthful indiscretions, in opposing his past follies to his present protestations. This was ticklish and difficult ground; he felt it to be so, but attempted to show that he had acted generously towards his wife, and produced a letter which appeared to contain proof of an infidelity which he had pardoned. This incident proved decisive, but in a way which he had not foreseen. The judges were of opinion, with D'Aguesseau, that a husband who had accused his wife of infidelity could not cohabit with her; and a decree of separation was accordingly pronounced. Mirabeau appealed the cause to the great council, and demanded the annulling of the judgment, but without success; the court of last resort being of the same opinion with the tribunal before which the cause had in the first instance been tried.

Mirabeau's life, for the next five years, presents one continued struggle with all kinds of difficulties and privations. Being destitute of the means of subsistence, and suspected by the authorities, he set out for London in 1784, accompanied by a Dutch girl who had succeeded Sophie in his affections; and there published, in French and English, his *Considérations sur l'Ordre de Cincinnatus*, which he had commenced in Paris under the auspices of Franklin. He translated Price's *Observations on the Importance of the American Revolution*, with *Reflections and Notes*, in which he was assisted by Turgot; and, about the same time, he published his *Doutes sur la Liberté de l'Escaut*, in opposition to the views of Joseph II., a production which was speedily followed by his *Lettre* to the same sovereign upon his prohibiting emigration. He attacked the *caisse d'es-compte*, the bank of Saint-Charles, and the water-company of Paris; and having been openly pointed out as the instrument of Panchaud, Clavière, and other speculators, he engaged in a furious controversy with Beaumarchais, who had been employed to reply on behalf of the company, and who treated him with a calm disdain, which was rendered still more offensive by ironical commendations. Mirabeau rejoined like a man whom contempt had rendered frantic; and the violent attack which he made on Beaumarchais, though deformed by gross personalities, is perhaps the most eloquent of all his writings. It produced a

great effect at Paris, and contributed not a little to his ulterior success. His activity was, in fact, boundless. Having become acquainted with a geographer, whose name M. Dumont does not remember, he meditated writing an universal geography; and if any one had offered him the elements of a Chinese grammar, he would no doubt have attempted a treatise on the Chinese language. He studied a subject whilst he was writing upon it, and he only required an assistant to furnish him with matter. "He could contrive," says Dumont, "to get notes and additions from twenty different hands; and had he been offered a good price, I am confident he would have undertaken to write even an encyclopædia." He had the art of finding out men of talent, and of successfully flattering those who could be of use to him. He worked upon them with insinuations of friendship and ideas of public benefit; whilst his interesting and animating conversation was like a hone which he employed to sharpen his tools. Nothing was lost to him; he was a sort of universal plagiarist, who appropriated for his own benefit the fruits of the reading and study of his friends. But he knew how to employ the information thus acquired, so as to appear to have always possessed it; and when he had begun a work, it was seen to make a rapid and daily progress.

This state of things, however, could not last long. His wants outran his means; his father yielded him no effectual assistance; and he was obliged to seek other resources. In these circumstances, he solicited employment from Calonne, who then directed the finances, and was by that minister sent on a secret mission to Berlin. This employment was given him for the triple object of getting rid of a troublesome suitor, of sounding by his means the dispositions of the young prince who was about to ascend the throne of Prussia, and of inducing the latter to consent to advance a considerable loan to France. The equivocal character in which Mirabeau appeared did not prevent him from evincing his usual zeal and activity. Being honoured with a favourable reception by the Duke of Brunswick, he also obtained the suffrage of the Great Frederick himself, whose last moments he witnessed. To the successor of that monarch, on the very day of his accession, he transmitted a letter, in which he ventured to give some advice, with which the young sovereign did not appear to be offended, though he felt himself under no obligation to follow it. Subsequently, being desirous to open the eyes of Frederick-William respecting the reveries of the illuminati, Mirabeau composed a pamphlet, in which he unsparingly ridiculed Lavater and Count Cagliostro. Nor, amidst these various occupations, did he lose sight of the interests of France. His despatches, addressed to M. de Calonne and to the Duke de Lauzun, communicated ample diurnal details respecting the cabinet of Berlin; and being always famished for money, as well as devoured by ambition, we find him in each despatch demanding gratifications and advancement. Meanwhile, a secret statistical table of Germany chanced to fall into his hands. He at once perceived its importance, and managed to get it translated by means of a valet who knew only German, and a French secretary who understood no language but his own. At the same time he acquired ample literary materials, and was indebted to Major Mauvillon for some invaluable documents, which, when classed and arranged by himself, formed the elements of his book on the Prussian monarchy (*Monarchie Prussienne*.) But his activity was too great to escape notice, and Frederick-William, not relishing the perspicacity and vigilance of so close an observer, ordered him to quit the Prussian territory, in which he had resided about eight months. He returned to Paris, and soon became deeply involved in fresh agitation and intrigue.

M. de Calonne was then placing his plans of administration under the protection of the first notables, whom he had

Mirabeau just convoked. Mirabeau at once plunged into these discussions, in the only way compatible with his precarious existence, namely, by publishing a violent diatribe, entitled *Dénonciation de l'Agiotage*, in which personalities were accumulated without reserve against both Calonne and Necker. The consequence was an order of the king, which condemned the pamphleteer to imprisonment in the castle of Saumur; but Mirabeau evaded the intended punishment, and, having placed himself in safety, published the *Suite de la Dénonciation*; and in his *Lettres à M. La Fayette*, as well as in his *Correspondance avec Cerutti*, he scrupled not to assail the reputation of Necker, which was then at its height. These productions appear to have made a considerable impression. In fact, Mirabeau gained much celebrity by his polemical writings. At a time when political subjects had not yet entered into the circulation of common ideas, when the art of pamphleteering was scarcely cultivated, and only a small number of writers ventured to engage in this species of warfare, they were attractive novelties; and their effect was enhanced by his dogmatic and tranchant manner of handling subjects which he had scarcely studied, and especially by the haughty and arrogant tone which he assumed towards his adversaries. But if he had aggrandized his reputation as a writer, his personal character had sunk to the very lowest possible state of degradation. His discreditable employment as a sort of licensed spy at Berlin, his open connection with the enemies of Necker, and his ingratitude to Calonne, made him be regarded as a dangerous enemy and a slippery friend; whilst his lawsuits with his family, his elopements, his imprisonments, and his morals, could not be overlooked, even in a city so lax as Paris; and hence his name was pronounced with detestation, and his company shunned, as if he had carried about with him some deadly infection. But common fame is almost always in excess either on the one side or the other. He was by no means the abandoned and demoralized monster he was at this time generally thought to be; on the contrary, there were high and redeeming qualities in his nature, which afterwards displayed themselves on a great theatre of action; and, amidst all his excesses, he never lost his respect for virtue, nor his taste for the society of those whose principles and habits formed a perfect contrast to his own.

In 1788, his *Monarchie Prussienne* appeared at Paris, in eight volumes 8vo, with an atlas in folio. This production consisted of a work written for him by Major Mauvillon, and of extracts from different memoirs procured at great expense. No one can for a moment suppose that, during a residence of only eight months at Berlin, Mirabeau could himself have executed a work of such magnitude, in which every possible information had been introduced respecting the geography, productions, manufactures, commerce, and military condition of Prussia, as well as concerning the religion, education, legislation, and administrative system of that country. But he had the merit of employing the talents of an officer who was scarcely known to the government he served; and the Prussian ministers must have been much surprised at finding that a man who had resided so short a time in the country could singly undertake so arduous a task, and succeed in supplying them with more materials than could be found in the united offices of their several departments. "The work," says Dumont, "is an illustration, by facts, of Adam Smith's principles of political economy; and it clearly proves that Prussia has always been a sufferer whenever she has departed from these principles."

His next publication was one of a much less creditable character. The *Histoire Secrète du Cabinet de Berlin* is an indiscreet revelation of the diplomatic manœuvres of Mirabeau, written in a spirit of bitter criticism, with all the licentious freedom of a libel; and it excited general indig-

nation against the author, who had unscrupulously violated the secrets of hospitality, and the confidence of his friends, as well as that of the government, in order to supply pabulum to public malignity. In this disgraceful production, the Emperor Joseph II., the king of Prussia, and particularly Prince Henry, who was then at Paris, were all equally ill treated. Louis XVI. conceived that some satisfaction was due to the diplomatic corps, who had been so grossly assailed, and accordingly the libel was adjudged by the parliament to be burned by the hands of the common hangman. The worst passage of Mirabeau's life is the publication of the Letters to Sophie; but that of the Berlin Correspondence is equally without justification, although on different grounds. In extenuation of this proceeding, it has been observed, that the whole object of his existence depended upon the supplies which it furnished; that without it his election in Provence would have been hopeless. But this is a sorry topic, even of palliation.

Great events were now near at hand. On the 27th of December 1788, the long-expected royal proclamation appeared, definitively convoking the States-general for May 1789. Need we ask whether Mirabeau now bestirred himself; whether or not he was off to Provence, to the assembly of the noblesse, with all his faculties screwed to the sticking-place? A prospect had at length opened to him of rising superior to the humiliation of his youth, and the contempt attached to the precarious and degraded life he had led; he seems to have had a presentiment of the part which he was soon destined to perform in a mighty revolution, now about to commence; and he lost no time in taking means to bring about the accomplishment of his destiny. In the list of the popular candidates his name was accordingly proclaimed, in all parts of Provence, beside that of Raynal; and he laboured with unwearied activity in stimulating public feeling, proclaiming the necessity of political regeneration, denouncing abuses, exposing tyranny and misgovernment, agitating and contending by day, writing pamphlets and paragraphs by night, and, in short, straining every nerve to attain the first and grand object of his ambition. Nevertheless, when he presented himself in the assembly of the noblesse to vote with his peers, the latter excluded him, upon the pretence that the possessors of fiefs alone had the right of sitting amongst them. Against this fatal decision, which confirmed the alienation of the most dangerous enemy which the ignorance and insolence of a privileged order raised up for their own overthrow, Mirabeau protested in eloquent and energetic terms, exposing the folly of his order, and prognosticating the doom which it was now preparing for itself. We can only afford room for two paragraphs of this celebrated remonstrance.

"What have I done that was so criminal?" he exclaimed. "I have wished that my order were wise enough to give to-day what will infallibly be wrested from it to-morrow; that it should receive the merit and glory of sanctioning the assemblage of the three orders, which all Provence loudly demands. This is the crime of your 'enemy of peace.' Or rather, I have ventured to believe that the people might be in the right. Ah, doubtless, a patrician soiled with such a thought deserves vengeance. But I am still guiltier than you think; for it is my belief that the people which complains is always in the right; that its indefatigable patience invariably waits the uttermost excesses of oppression, before it can determine on resisting; that it never resists long enough to obtain complete redress, and does not sufficiently know, that to strike its enemies into terror and submission, it has only to stand still; that the most innocent as the most invincible of all powers is the power of refusing to act. I believe after this manner; punish the enemy of peace."

"In all countries, in all times, aristocrats have implaca-

Mirabeau. bly persecuted the people's friends; and if, by some singular combination of fortune, there chanced to arise such an one in their own circle, it was he above all whom they struck at, eager to inspire wider terror by the elevation of their victim. Thus perished the last of the Gracchi by the hands of the patricians; but, being struck with the mortal stab, he flung dust towards heaven, and called on the avenging deities; and from this dust sprang Marius, —Marius, not so illustrious for exterminating the Cimbri as for overturning in Rome the tyranny of the noblesse."

It is admitted by his enemies, that during his sojourn in Provence, Mirabeau gave proofs of equal ability and moderation. Surrounded by seditious movements, he repeatedly acted as mediator between the insurrection and the authorities, who would probably not have been sorry to find an occasion or pretext for proceeding against him. He restrained the violence of the multitude, by whom he was borne along in triumph; and being recommended to the suffrages of the electors of the *tiers-état*, he was proclaimed deputy both at Aix and at Marseilles. He made choice of the former, and immediately set out for Paris, to endeavour to arrange certain prosecutions which he had drawn upon himself by the publication of his despatches from Berlin. On the 4th of May 1789, Madame de Staël, looking from a window in the principal street of Versailles, as the deputies walked in procession from the church of Notre Dame to that of Saint Louis to hear high mass and be there constituted States-general, saw and above all distinguished the Count de Mirabeau amongst those nobles who had been deputed to the third estate. "The opinion men had of his genius," says the celebrated daughter of Necker, "was singularly augmented by the fear entertained of his immorality; and yet it was this very immorality which straitened the influence his astonishing faculties were to secure him. You could not but look long at this man, when once you had noticed him. His immense black head of hair distinguished him amongst them all; you would have said his force depended on it, like that of Samson. His face borrowed new expression from its very ugliness; his whole person gave you the idea of an irregular power, but a power such as you would figure in a tribune of the people." This description of his personal appearance seems to be as just as it is striking. In regard to character, he was so fully aware that if he had enjoyed personal consideration all France would have been at his feet, that there were moments when he would have consented to pass seven times through the heated furnace to purify the name of Mirabeau.

Mirabeau's history during the remaining twenty-three months of his life falls not to be written here; yet it is an astonishing passage, into which, short as it proved, are crowded the history of the Revolution in its first development, and that of the sudden and undisputed ascendancy which he gained over the National Assembly, the Revolution itself, and indeed all France. When he appeared in the hall of the States-general, and his name was first read out, a disapproving murmur arose from the assembly, followed by hooting, instead of the applause with which some other well-known names had been greeted. Insult and contempt showed how low he stood in the estimation of his colleagues. He perceived and felt the disrespect into which he had fallen; yet by his lofty and undaunted bearing he evinced his inherent sense of superiority, and scowled defiance at the murmurers. He was indeed the member of members; the most notable single element in that remarkable assembly; the man who, after a little time, was to become a power in the Revolution, to brave the court, to overawe the factions, and to exercise an undisputed supremacy. In one of those moments which are cardinal, and decisive for centuries, he visibly saved, by

his own force and energy, the existence of the Constituent Assembly. On the 23d of June, the royal proclamation was promulgated, ordaining the assembly to dissolve, and to meet again on the morrow as the separate third estate. A military force was at hand; the king's orders were express; and the Bastille, or even the scaffold itself, might be the penalty of disobedience. Yet Mirabeau disobeyed. When all around him were dismayed and panic-stricken, he raised his commanding voice to restore their faltering courage, and to re-animate that assembly which had but lately murmured at the very sound of his name. De Brézé entered with the king's renewed order to separate. "Gentlemen," said he, "you have heard the king's commands." "Yes, sir," replied Mirabeau, "we have heard what the king has been advised to say; and you, who cannot be the interpreter of his meaning to the States-general, you who have neither vote, nor seat, nor right of speech here, you are not the man to remind us of it. Go, sir, tell those who sent you that we are here by the will of the nation, and that nothing but the force of bayonets shall drive us hence." This was not a mere bravado. It was giving form and expression to feebler but similar sentiments; it was imparting energy to less concentrated and less resolute wills. Mirabeau possessed in a high degree the courage produced by excitement; and he was endowed with wonderful presence of mind. Hence he went through the Revolution like a force, commanding and overruling all. Whilst innumerable theorists and pedants were manufacturing their paper constitution, which "proved but the almanac of a single year," he looked not at speculations about social contracts, but at men and things; discerning what was to be done, and straightway proceeding to do it. He alone was capable of saving the monarchy on the one hand, and of repelling anarchy on the other. He fascinated, overawed, and subjugated every one. When the court found it necessary to treat with him, even Marie Antoinette was charmed with the tribune of the people, whom she had had so much cause to dread and to hate. In a word, he was the man of the Revolution, the king of that mighty popular movement, whilst he lived; and only with life would he in all probability have lost that command of it, which, by his power, his address, and his presence of mind, he had gained. But, unhappily, his allotted months were fast running out. Never were such wonders, such prodigies, crowded into so short a space of time; but the waste of energy rapidly impaired even his iron frame; and his last hour, a sorrowful one for France, was nigh at hand.

His health was now rapidly declining. "If I believed in slow poisons," said he to Dumont, "I should think myself poisoned. I feel that I am dying by inches, that I am consuming in a slow fire." Dumont observed to him that his mode of life would long ago have destroyed any man less robust than he. Not an instant of rest from seven in the morning until ten or eleven at night; continual conversations, agitations of mind, and excitement of every passion; too high living, in food only, for he was temperate in liquor. "You must be a salamander," said Dumont, "to live in the fire which is consuming you." The irritation of his system, at this time, produced ophthalmia, and, whilst he was president of the assembly, he sometimes found it necessary to apply leeches to his eyes, in the interval during the adjournment of the sitting from the morning to the evening; and he attended the assembly with his neck covered with linen, in order to staunch the blood. His parting words to Dumont were memorable. "I shall die at the stake," said he, "and we shall never perhaps meet again. When I am gone, my value will be appreciated. Misfortunes to which I have put a stop were overwhelming France in every direction; but that base faction whom I now overawe will again be let loose upon

Mirabeau. the country. I have none but direful anticipations. Ah, my friend, how right were we when, in the beginning, we tried to prevent the commons from being declared a National Assembly. This is the origin of the evil. Since they have gained that point, they have not ceased to show that they are unworthy of confidence. They wanted to govern the king, instead of being governed by him; but neither they nor he will govern; *a vile faction will rule the country, and debase it by the most atrocious crimes.*"

In the same prophetic spirit, and with the same instinctive penetration, he observed to Talleyrand, "I take with me the last shreds of the monarchy." The severity of his judgments was, at the time, attributed to hatred or jealousy; but it has been fully confirmed by succeeding events; nor was there a man of any consequence in the assembly, the sum of whose conduct did not correspond with the opinion which Mirabeau had formed of him. His last illness, which was acute enteritis, brought on by excesses, lasted only four or five days, during which he suffered the most excruciating agony; yet, in the intervals of pain, when the dreadfully violent fits were over, he would resume his serenity, his mildness, and his amiable attentions to those around him. He perceived that he was an object of general interest, and he never for a moment ceased to speak and to act as if he were a great and noble personage performing his part. In the extreme agony of convulsions, and covered with a chilly perspiration, there were moments when it required more than the force of a philosopher to support life; yet he preserved to the last his spirit unbroken, and, to use the happy expression of Talleyrand, dramatised his death. This extraordinary man expired in the arms of his friends, on the morning of the 2d of April 1791. No religious aspirations arose to hallow or console his last moments; he died professing the most decided materialism, the blank and cheerless creed of the time.

Mirabeau had a degree of confidence in his own powers, which supported him in difficulties under which another would have sunk. His imagination loved whatever was great, and his mind possessed extraordinary powers of discrimination. He had natural good taste, which he had cultivated by reading the best authors of several nations. Without any depth of information, he made good use of the little he possessed; but, whether from some natural defect of judgment, or from the influence of feeling and passion, he often proved an unsafe guide in speculation, and still more frequently in action. What he possessed beyond other men was an eloquent and impassioned soul, which, the instant it was excited, animated every feature of his countenance; and nothing was more easy than to bring on the requisite degree of excitement. He had been accustomed, from his youth, to consider the two great questions of politics and government; but he was not qualified to enter deeply into them. The work of discussion, examination, and doubt, was beyond his reach; he had too much warmth and effervescence of mind for didactic method or laborious application. His mind proceeded by starts and leaps, but his conceptions were bold and vigorous. He abounded in forcible expressions, of which he made a particular study; and he was peculiarly qualified to shine in a popular assembly, at a stormy period, when force and audacity were the necessary passports to success.

Of his genius, the best monuments which remain are his speeches, and these were not always, indeed seldom, his own composition. Dumont, Duroverai, Clavière, Reybaz, and other men of distinguished ability, did more than assist him. But some of the finest are known to have been his own; and the greatest passages, those which produced the most magical effects, were the inspiration of the moment. Indeed he never appeared greater than when called to preside over the assembly, and of course thrown

entirely upon his own resources. Envy had contributed to his elevation; his enemies had hoped that, in the president's chair, a portion of his natural fire would be quenched, and that his influence would suffer a corresponding diminution. But they found themselves wofully disappointed in their calculation. Never had this office been so well filled, and he displayed in it a new kind of talent. He introduced order and clearness into the proceedings; he simplified the forms, which were but ill understood; he explained a question or put down a tumult by a single word; he distinguished himself by the precision of his observations, and his answers to the several deputations at the bar, which were always remarkable for dignity and elegance; and by his activity, impartiality, and presence of mind, he increased his reputation, and added splendour to his talents in an office which had proved a quicksand to many of his predecessors. "His enemies, and those jealous of his eloquence," says Dumont, "who had voted for him, in order thereby to cast him into the shade and reduce him to silence, were bitterly disappointed when they saw him add another wreath to the chaplet of his glory."

At the same time, it must be confessed that no inconsiderable portion of his reputation, both as an orator and a writer, was usurped and fictitious. He felt himself absolutely incapable of writing upon any subject, except he was guided and supported by the work of another. His style, naturally strained, degenerated into turgescence, and he was soon disgusted with the emptiness and the incoherence of his own ideas. But when he had materials to work upon, he could prune and connect them, impart to them a greater degree of life and force, and impress upon the whole the stamp of true eloquence. In fact, he gave splendour to whatever he touched, by introducing here and there luminous thoughts, original expressions, and passages full of fire and eloquence. But the most remarkable faculty he possessed was that of discovering obscure talents; applying to each the degree of encouragement necessary to its peculiar character; and animating those who possessed them with his own zeal, so as to make them eagerly co-operate in a work of which he was to reap all the credit. This was the great secret of his success. "When I worked for Mirabeau," said Dumont, "I seemed to feel the pleasure of an obscure individual who had changed his children at nurse, and introduced them into a great family. He would be obliged to respect them, although he was not their father." Indeed Mirabeau attached himself so strongly to his adopted children, that he felt for them the affection of a parent; and, even in his last illness, he gave to M. de Talleyrand a speech upon wills, which had been written for him by Reybaz, saying, "There! these are the last thoughts the world shall have of mine; I deposit this manuscript with you; read it when I am no more; it is my legacy to the assembly." Such was the Count de Mirabeau. On his very deathbed he preserved his thirst for artificial fame, when he had acquired so much personal glory that his reputation required not to be decked out with the laurels of others. He had an insatiable appetite for appropriating the labours of others.

As a political orator Mirabeau was in some respects superior to all other men. He had a rapid intuition, a quick and sure perception of the feelings of the assembly, and well knew how to apply his entire strength to the point of resistance, without exhausting his means. No orator ever did so much with a single word or phrase, nor hit the mark with so sure an aim; none but Mirabeau ever forced the general opinion by a happy insinuation, or by a strong expression. In the tribune he was immovable; no agitation in the assembly had the least effect on him; and he retained the command of his temper, even under the severest personal attacks. But one thing was wanting to make him a perfect political orator, namely, the power of

Mirabeau. discussion. His mind could not embrace a chain of reasoning or evidence, nor could he refute methodically; and hence, after a brilliant exordium, he had often no alternative but to abandon the field to his adversaries. He was powerless in reply, because he had not taken the pains to anticipate objections and discuss details. Satisfied with a happy turn of expression, or a striking thought, he never gave himself the trouble of studying a subject sufficiently to be able to discuss it, and maintain the opinion he had advanced. He seized every thing with marvellous facility, but developed nothing. He wanted the practice of refutation; this great art, so indispensable to a political orator, was altogether unknown to him. The triumph of Mr Fox consisted in the possession of that talent which Mirabeau wanted; in reply he was irresistible. He recapitulated all the arguments of the adverse party, put them in a new light, and gave them more force; yet having thus placed himself in the most difficult situation imaginable, he never appeared stronger than when he seemed about to be overthrown. The only speakers in the National Assembly who possessed any share of this faculty were Maury, Clermont-Tonnère, Barnave, and Thouret. Mirabeau's voice was full, manly, and sonorous; and being always powerful yet flexible, it could be heard as distinctly when he lowered as when he raised it. His ordinary manner of speaking was slow; and, in his impassioned moments, the feeling which made him dwell upon certain words to give them emphasis prevented him from ever speaking rapidly. Amongst his personal advantages he counted his robust frame, his size, and his strongly-marked features seared with the small-pox. His ugliness was so great as almost to become proverbial; but his natural vanity, almost as exaggerated as his deformity, even drew from its excess materials of self-gratification. "Personne, disait-il, ne connaît la puissance de ma laideur." The power of his eye, however, was undeniable; and the spirit and expression which his mind threw into his countenance made it any thing rather than uninteresting or disgusting.¹

After what has been said, it is scarcely necessary to dwell on his personal character. Though not himself a moral man, he had a decided taste for the society of those whose rigidity of principle and severity of morals contrasted with the laxity of his own; and, even in the midst of his excesses, he had preserved a certain dignity and elevation of mind, combined with an energy of character, which distinguished him from the effeminate and exhausted rakes that swarmed in Paris. Slave as he too generally proved himself to the love of indulgence, his courage was above all suspicion; and even his share of a virtue far more rare, fortitude under calamity, surpassed that of most other men. All the hardships he had undergone, all the torments he had suffered from so many forms of ingenious persecution, never for a moment infused any bitterness into his disposition, which was originally kind and benevolent. "I never knew a man," says Dumont, "more jealous of the esteem of those whom he himself esteemed, or one who could be acted upon more easily, if excited by the sentiment of high honour." But, unfortunately, there was nothing uniform and permanent in his character. He was the creature of impulse, and obeyed too many impetuous masters. When burning with pride or jealousy, his passions were terrible; he was no longer master of himself, and committed the most dangerous acts of imprudence. In connecting himself with the court, during the last six months of his life, Mirabeau had no other object than to gratify his habits of expensive indulgence, and to become

prime minister. He was not a traitor to the popular cause, because he was too able a tactician to commit so great a political error; but it is nevertheless impossible not to agree with Dumont in reprobating the sudden turn which he took, when policy required a suspension of hostilities, and the quick transition from menaced and even boastful destruction, to absolute neutrality. If not sold to the court, he was at least paid by it; and although it might be true that his object was, if possible, to save the monarchy, yet the mode in which he proposed to accomplish this object was neither creditable in itself, nor likely to be attended with success; whilst the "enormous price" paid for his expected services fixes the indelible stain of venality on his memory. Still his death was a great calamity to France. Whilst Mirabeau lived, Robespierre and his satellites durst no more have ventured to show themselves, than bats to fly about in the sunshine of noonday. He was as omnipotent in the Jacobin Club as in the Constituent Assembly.

Some anecdotes of this extraordinary man may not be altogether out of place here. He was fond of nicknames, and often peculiarly happy in bestowing them. He called the king of Prussia *Alaric-Cottin*; he designated Siéyes by the name of *Mahommed*; he called D'Espréménil, a conspirator in a small way, *Crispin-Cataline*; he baptized the rigid Camus by the appellation of the *Drapeau Rouge*, because he had a fiery countenance, with a blood-coloured nose; and he painted Lafayette by the sobriquet of *Grandison-Cromwell*. Of Necker, to whom he was invariably unjust, he observed, "He is like a clock which always goes too slowly;" and again, "Malebranche saw every thing in God," said he, "but Necker sees every thing in Necker." Of the National Assembly he remarked, "It has Hannibals enow, it only wants a Fabius." Speaking of the illusions which, having once governed men, were for ever destroyed, he said, "We have long been looking through a magic lantern, but the glass is now broken." "When a pond is full," said he, "a single mole, by piercing the bank, may cause an inundation." Dining one day with the Count de Montmorin, he was asked by the latter what he thought of his brother, who, being a fat and heavy man, was called by the people *Mirabeau-Tonneau*, or *Barrel-Mirabeau*. "He would be a man of wit and a scapegrace in any family but ours," replied Mirabeau. The viscount, however, was also an epigrammatist in his own way. Being reproached by his friends with having, one evening, attended the assembly almost in a state of inebriation, Barrel-Mirabeau replied, "My brother has left me only that vice." Mirabeau had very wisely determined to decline every duel during the sittings of the National Assembly; and hence doubts have been entertained of his personal courage, although without the shadow of a foundation. "They can procure as many bullies as they like," said he, "and thus, by duels, get rid of every one who opposes them. For if a man killed ten of these fellows, he might fall by the eleventh." All his ambition was centred in the idea of becoming prime minister of France, because he thought, and not without reason, that he could eclipse every minister who had preceded him. He felt himself powerful enough to attract within the sphere of his patronage every man of distinguished abilities, and he conceived he would be able to form a constellation of talents, the brightness of which would dazzle Europe.

Besides the works to which particular reference has already been made in the course of this article, Mirabeau was the author of the following, viz. 1. *Sur Mosès Mendelsohn et la Reforme Politique des Juifs*, London, 1787, in 8vo; 2.

¹ The arch reply of Talleyrand is well known. Mirabeau was dilating on the qualities required in him who should aspire to govern France under a free constitution: "Il faut qu'il soit éloquent, fougueux, noble," and so on he went, enumerating qualities notoriously possessed by himself; when the witty statesman added, "Et qu'il soit tracé de la petite vérole, n'est-ce pas?"

Mirabello Lettre sur Cagliostro et Lavater, Berlin, 1786; 3. Observations sur Bicêtre, Paris, 1788; 4. Lettre à Guibert sur son Eloge de Frédéric, et son Essai de Tactique, ibid. 1788; 5. De l'Usure; 6. Aux Bataves sur le Stathoudérat, 1788; 7. Conseils à un jeune Prince qui veut refaire son Education, 1788; 8. Théorie de la Royauté, d'après Milton, Paris, 1791; 9. Lettres à un de ses Amis en Allemagne (Mauvillon), écrites de 1786 à 1790, Brunswick, 1792; 10. Lettres à Champfort, Paris, 1797; 11. Elégies de Tibulle, et Baisers de Jean Second, Tours, 1796, in three vols.; 12. Lettres Inédites de Mirabeau, Paris, 1806.

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Miracle.

(Dumont, *Souvenirs de Mirabeau; Mémoires Biographiques, Littéraires, et Politiques de Mirabeau*, Paris, 1834-1836; *Biographie Universelle*, art. MIRABEAU; Edinburgh Review, vol. lxii.; Chaussard, *Esprit de Mirabeau*, Paris, 1797 and 1804).

(A.)

MIRABELLO, one of the circles into which the Turkish island of Candia is divided. It is a fruitful district in the north-east part of the island, and yields a surplus of corn, oil, and fruits. The chief place, of the same name, is situated on the Bay of Spinalonga, where there is a good anchorage. It is the see of a bishop, and contains 1500 inhabitants. Long. 25. 5. E. Lat. 35. 15. N.

MIRACLE, in its original sense, is a word of the same import with *wonder*; but in its usual and more appropriate signification it denotes "an effect contrary to the established constitution and course of things, or a sensible deviation from the known laws of nature."

That the visible world is governed by stated general rules, or that there is an order of causes and effects established in every part of the system of nature which falls under our observation, is a fact which cannot be controverted. If the Supreme Being, as some have supposed, be the only real agent in the universe, we have the evidence of experience, that, in the particular system to which we belong, he acts by stated rules. If he employs inferior agents to conduct the various motions from which the phenomena result, we have the same evidence that he has subjected those agents to certain fixed laws, commonly called the laws of nature. Upon either hypothesis, effects which are produced by the regular operation of these laws, or which are conformable to the established course of events, are properly called *natural*; and every contradiction to this constitution of the natural system, and the corresponding course of events in it, is called a *miracle*.

If this definition of a miracle be just, no event can be deemed miraculous merely because it is strange, or even to us unaccountable; since it may be nothing more than a regular effect of some unknown law of nature. In this country earthquakes are rare; and for monstrous births perhaps no particular and satisfactory account can be given; yet an earthquake is as regular an effect of the established laws of nature as any of those with which we are most intimately acquainted; and, under circumstances in which there would always be the same kind of production, the monster is nature's genuine issue. It is therefore necessary, before we can pronounce any effect to be a true miracle, that the circumstances under which it is produced be known, and that the common course of nature be in some degree understood; for in all those cases in which we are totally ignorant of nature, it is impossible to determine what is, or what is not, a deviation from its course. Miracles, therefore, are not, as some have represented them, appeals to our ignorance. They suppose some antecedent knowledge of the course of nature, without which a proper judgment cannot be formed concerning them, though with it their reality may be so apparent as to prevent all possibility of a dispute.

Thus, were a physician to cure a blind man of a cataract by anointing his eyes with a chemical preparation which we had never before seen, and to the nature and ef-

fects of which we were absolute strangers, the cure would undoubtedly be wonderful; but we could not pronounce it miraculous, because, for any thing known to us, it might be the natural effect of the operation of the unguent upon the eye. But were he to recover his patient merely by commanding him to see, or by anointing his eyes with spittle, we should with the utmost confidence pronounce the cure to be a miracle, because we know perfectly that neither the human voice nor human spittle have, by the established constitution of things, any such power over the diseases of the eye. No one is now ignorant, that persons apparently dead are often restored to their families and friends by being treated in the manner recommended by the Humane Society. To the vulgar, and sometimes even to men of science, these effects appear very wonderful; but as they are known to be produced by physical agency, they can never be considered as miraculous deviations from the laws of nature. On the other hand, no one could doubt of his having witnessed a real miracle who had seen a person that had been four days dead come alive out of his grave at the call of another, or who had even beheld a person exhibiting all the symptoms of death instantly resuscitated merely by being desired to live. So easy is it, in all cases in which the course of nature is understood, to determine whether any particular event be really a miracle; whilst in circumstances where we know nothing of nature and its course, even a true miracle, were it performed, could not be admitted as such, nor carry any conviction to the mind of a philosopher.

If miracles be effects contrary to the established constitution of things, we are certain that they will never be performed on trivial occasions. The constitution of things was established by the creator and governor of the universe, and is undoubtedly the offspring of infinite wisdom pursuing a plan for the best of purposes. From this plan no deviation can be made but by God himself, or by some powerful being acting with his permission. The plans devised by wisdom are steady in proportion to their perfection, and the plans of infinite wisdom must be absolutely perfect. From this consideration some men have ventured to conclude that no miracle was ever wrought, nor can rationally be expected; but maturer reflection must soon satisfy us that all such conclusions are hasty.

Man is unquestionably the principal creature in this world, and apparently the only one in it who is capable of being made acquainted with the relation in which he stands to his Creator. We cannot, therefore, doubt but that such of the laws of nature as extend not their operation beyond the limits of this earth were established chiefly, if not solely, for the good of mankind; and if, in any particular circumstances, that good can be more effectually promoted by an occasional deviation from those laws, such a deviation may reasonably be expected. Were man, in the exercise of his mental and corporeal powers, subjected to the laws of physical necessity, the circumstances supposed would indeed never occur, and of course no miracle could be admitted. But such is not the nature of man.

Without repeating what has been said elsewhere (see *METAPHYSICS*, part iii. chap. 5) of necessity and liberty, we shall here take it for granted that the relation between motives and actions is different from that between cause and effect in physics; and that mankind have such a command over themselves as that by their voluntary conduct they can make themselves in a great degree either happy or miserable. We know likewise from history, that, by some means or other, almost all mankind were once sunk in the grossest ignorance of the most important truths; that they knew not the Being by whom they were created and supported; that they paid divine adoration to stocks, stones, and the vilest reptiles; and that they were slaves to the most impious, cruel, and degrading superstitions.

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Miracle.

From this depraved state it was surely not unworthy of the common Father of all to rescue his helpless creatures, to enlighten their understandings that they might perceive what is right, and to present to them motives of sufficient force to engage them in the practice of it. But the understandings of ignorant barbarians cannot be enlightened by arguments, because of the force of such arguments as regard moral science they are not qualified to judge. The philosophers of Athens and Rome inculcated, indeed, many excellent moral precepts, and they sometimes ventured to expose the absurdities of the reigning superstition; but their lectures had no influence upon the multitude; and they had themselves imbibed such erroneous notions respecting the attributes of the Supreme Being, and the nature of the human soul, and converted these notions into first principles, of which they would not permit an examination, that even amongst them a thorough reformation was not to be expected from the powers of reasoning. It is likewise to be observed, that there are many truths of the utmost importance to mankind which unassisted reason could never have discovered. Amongst these we may confidently reckon the immortality of the soul, the terms upon which God will be reconciled to sinners, and the manner in which that all-perfect Being may be acceptably worshipped; about all of which philosophers were in such uncertainty, that, according to Plato, "whatever is set right, and as it should be, in the present evil state of the world, can be so only by the particular interposition of God."

An immediate revelation from heaven seemed, therefore, the only method by which infinite wisdom and perfect goodness could reform a bewildered and vicious race. But this revelation, at whatever time we suppose it given, must have been made directly either to some chosen individuals commissioned to instruct others, or to every man and woman for whose benefit it was ultimately intended. Were every person instructed in the knowledge of his duty by immediate inspiration, and were the motives to practise it brought home to his mind by God himself, human nature would be wholly changed: Men would not be masters of their own actions; they would not be moral agents, nor by consequence be capable either of reward or of punishment. It remains, therefore, that if God has been graciously pleased to enlighten and reform mankind, without destroying that moral nature which is essential to virtue, he can have done it only by revealing his truth to certain chosen instruments, who were the immediate instructors of their contemporaries, and through them have been the instructors of succeeding ages.

Let us suppose this to have been actually the case, and consider how those inspired teachers could communicate to others every truth which had been revealed to themselves. They might easily, if it was part of their duty, deliver a sublime system of natural and moral science, and establish it upon the common basis of experiment and demonstration; but what foundation could they lay for those truths which unassisted reason cannot discover, and which, when they are revealed, appear to have no necessary relation to any thing previously known? To a bare affirmation that they had been immediately received from God, no rational being could be expected to assent. The teachers might be men of known veracity, whose simple assertion would be admitted as sufficient evidence for any fact in conformity with the laws of nature; but as every man has the evidence of his own consciousness and experience that revelations from heaven are deviations from these laws, an assertion so apparently extravagant would be rejected as false, unless supported by some better proof than the mere affirmation of the teacher. In this state of things, we cannot conceive any evidence sufficient to make such doctrines be received as the truths of God, except the

power of working miracles committed to him who taught them. This would, indeed, be fully adequate to the purpose. For if there were nothing in the doctrines themselves impious, immoral, or contrary to the truths already known, the only thing which could render the teacher's assertion incredible, would be its implying such an intimate communion with God as is contrary to the established course of things, by which men are left to acquire all their knowledge by the exercise of their own faculties. Let us now suppose one of those inspired teachers to tell his countrymen that he did not desire them, upon his *ipse dixit*, to believe that he had any preternatural communion with the Deity, but that for the truth of his assertion he would give them the evidence of their own senses; and after this declaration, let us suppose him immediately to raise a person from the dead in their presence, merely by calling upon him to come forth out of his grave. Would not the only possible objection to the man's veracity be removed by this miracle? and would not his assertions that he had received such and such doctrines from God be as fully credited as if it had related to the most common occurrence? Undoubtedly it would; for when so much preternatural power was visibly communicated to this person, no one could possibly have reason to question his having received an equal portion of preternatural knowledge. A palpable deviation from the known laws of nature in one instance, is a sensible proof that such a deviation is possible in another; and in such a case as this, it is the witness of God to the truth of a man.

Miracles, then, under which we also include prophecy, are the only direct evidence which can be given of divine inspiration. When a religion, or any religious truth, is to be revealed from heaven, they appear to be absolutely necessary to enforce its reception amongst men; and this is the only case in which we can suppose them necessary, or believe for a moment that they ever have been or will be performed.

The history of almost every religion abounds with relations of prodigies and wonders, and of the intercourse of men with the gods; but we know of no religious system, those of the Jews and the Christians excepted, which appealed to miracles as the sole evidence of its truth and divinity. The pretended miracles mentioned by Pagan historians and poets are not said to have been publicly wrought in order to enforce the truth of a new religion contrary to the reigning idolatry. Many of them may be clearly shown to have been mere natural events; others of them are represented as having been performed in secret, upon the most trivial occasions, and in obscure and fabulous ages long prior to the era of the writers by whom they are recorded; and such of them as at first view appear to be best attested, are evidently tricks contrived for interested purposes, to flatter power, or to promote the prevailing superstitions. For these reasons, as well as on account of the immoral character of the divinities by whom they are said to have been wrought, they are altogether unworthy of examination, and carry in the very nature of them the completest proofs of falsehood and imposture.

But the miracles recorded of Moses and of Christ bear a very different character. None of them is represented as wrought upon trivial occasions. The writers who mention them were eye-witnesses of the facts, which they affirm to have been performed publicly, in attestation of the truth of their respective systems. They are, indeed, so incorporated with these systems, that the miracles cannot be separated from the doctrines; and if the miracles were not really performed, the doctrines cannot possibly be true. Besides all this, they were wrought in support of revelations which opposed all the religious systems, superstitions, and prejudices of the age in which they were given; a circumstance which of itself sets them, in point of authority,

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Miracle. infinitely above the Pagan prodigies, as well as the pretended miracles of the church of Rome.

It is indeed, we believe, universally admitted, that the miracles mentioned in the book of Exodus and in the four Gospels might, to those who saw them performed, be sufficient evidence of the divine inspiration of Moses and of Christ; but to us it may be thought that they are no evidence whatever, as we must believe in the miracles themselves, if we believe in them at all, upon the bare authority of human testimony. Why, it has been sometimes asked, are not miracles wrought in all ages and countries? If the religion of Christ was to be of perpetual duration, every generation of men ought to have complete evidence of its truth and divinity.

To the performance of miracles in every age and in every country, perhaps the same objections would lie as to the immediate inspiration of every individual. Were those miracles universally received as such, men would be so overwhelmed with the *number* rather than with the *force* of their authority, as hardly to remain masters of their own conduct; and in that case the very end of all miracles would be defeated by their frequency. The truth, however, seems to be, that miracles so frequently repeated would not be received as such, and of course would have *no* authority; because it would be difficult, and in many cases impossible, to distinguish them from natural events. If they recurred regularly at certain intervals, we could not prove them to be deviations from the known laws of nature, because we should have the same experience for the one series of events as we have for the other; for the regular succession of preternatural effects, as for the established constitution and course of things.

Be this, however, as it may, we shall take the liberty to affirm, that, for the reality of the Gospel miracles, we have evidence as convincing to the reflecting mind, though not so striking to vulgar apprehension, as those had who were contemporary with Christ and his apostles, and actually saw the mighty works which he performed. To the admirers of Mr Hume's philosophy this assertion will appear an extravagant paradox; but we hope to demonstrate its truths from principles which, consistently with himself, that author could not have denied. He has indeed endeavoured to prove,¹ that "no testimony is sufficient to establish a miracle;" and the reasoning employed for this purpose is, that "a miracle being a violation of the laws of nature which a firm and unalterable experience has established, the proof against a miracle, from the very nature of the fact, is as entire as any argument from experience can be; whereas our experience of human veracity, which (according to him) is the sole foundation of the evidence of testimony, is far from being uniform, and can therefore never preponderate against that experience which admits of no exception." This boasted and plausible argument has been examined by Dr Campbell,² who justly observes, that so far is experience from being the sole foundation of the evidence of testimony, that, on the contrary, testimony is the sole foundation of by far the greater part of what Mr Hume calls firm and unalterable experience; and that if in certain circumstances we did not give an implicit faith to testimony, our knowledge of events would be confined to those which had fallen under the immediate observation of our own senses.

But although Dr Campbell has exposed the sophistry of his opponent's reasoning, and overturned the principles from which he reasons, we are persuaded that he might safely have joined issue with him upon those very principles. To us, at least, it appears that the testimony upon which we receive the Gospel miracles is precisely of that

kind which Mr Hume has acknowledged sufficient to establish even a miracle. "No testimony," says he, "is sufficient to establish a miracle, unless the testimony be of such a kind that its falsehood would be more miraculous than the fact which it endeavours to establish. When one tells me that he saw a dead man restored to life, I immediately consider with myself whether it be more probable that this person should either deceive or be deceived, or that the fact which he relates should really have happened. I weigh the one miracle against the other; and according to the superiority which I discover, I pronounce my decision, and always reject the greater miracle." In this passage every reader may remark, what did not escape the perspicacious eye of Dr Campbell, a strange confusion of terms; but as all miracles are equally easy to the Almighty, and as Mr Hume has elsewhere observed, that "the raising of a feather, when the wind wants ever so little of a force requisite for that purpose, is as real a miracle as the raising of a house or a ship into the air," candour obliges us to suppose, that by talking of greater and less miracles, and of always rejecting the greater, he meant nothing more but that, of two deviations from the known laws of nature, he always rejects that which in itself is least probable.

If, then, it can be shown that the testimony given by the apostles and other first preachers of Christianity to the miracles of their Master, would, upon their supposition that those miracles were not really performed, have been as great a deviation from the known laws of nature as the miracles themselves, the balance must be considered as equally poised by opposite miracles; and whilst it continues so, the judgment must remain in a state of suspense. But if it shall appear, that in this case the false testimony would have been a deviation from the laws of nature less probable in itself than the miracles recorded in the Gospels, the balance will instantly be destroyed; and, by Mr Hume's maxim, we shall be obliged to reject the supposition of falsehood in the testimony of the apostles, and admit the miracles of Christ to have been really performed.

In this argument we need not waste time in proving that those miracles, as they are represented in the writings of the New Testament, were of such a nature, and performed before so many witnesses, that no imposition could possibly be practised upon the senses of those who affirm that they were present. From every page of the Gospels this is so evident, that the philosophical adversaries of the Christian faith never suppose the apostles to have been themselves deceived, but boldly accuse them of bearing false witness. But if this accusation be well founded, their testimony itself is as great a miracle as any which they record of themselves or of their Master.

It has been shown elsewhere (see the article METAPHYSICS), that by the law of association, which is one of the laws of nature, mankind, in the very process of learning to speak, necessarily learn to speak the truth; that ideas and relations are in the mind of every man so closely associated with the words by which they are expressed in his native tongue, and in every other language of which he is master, that the one cannot be entirely separated from the other; that therefore no man can on any occasion speak falsehood without some *effort*; that by no effort can a man give consistency to an unpremeditated detail of falsehood, if it be of any length, and include a number of particulars; and that it is still less possible for several men to agree in such a detail, when at a distance from each other, and cross-questioned by their enemies.

This being the case, it follows, if the testimony of the apostles to their own and their Master's miracles be false,

Miracle.

¹ Essay on Miracles.

² Dissertation on Miracles.

Miracle. either that they must have concerted a consistent scheme of falsehood, and agreed to publish it at every hazard; or that God, or some powerful agent appointed by him, must have dissolved all the associations formed in their minds between ideas of sense and the words of language, and arbitrarily formed new associations, all in exact conformity to each other, but all, at the same time, in direct contradiction to truth. One or other of these events must have taken place, because, upon the supposition of falsehood, there is no other alternative. But such a dissolution and formation of associations as the latter implies must, to every man who shall attentively consider it, appear to be as real a miracle, and to require as great an exertion of power, as the resurrection of the dead. Nor is the supposed voluntary agreement of the apostles in a scheme of falsehood an event less miraculous. When they sat down to fabricate their pretended revelation, and to contrive a series of miracles to which they were unanimously to appeal for its truth, it is plain, since they proved successful in their daring enterprise, that they must have clearly foreseen every possible circumstance in which they could be placed, and have prepared consistent answers to every question which could be put to them by their most inveterate and most enlightened enemies; by the statesman, the lawyer, the philosopher, and the priest. That such foreknowledge as this would have been miraculous, will not surely be denied; since it forms the very attribute which we find it most difficult to allow even to God himself. It is not, however, the *only* miracle which this supposition would compel us to swallow. The very *resolution* of the apostles to propagate the belief of false miracles in support of such a religion as that which is taught in the New Testament, is about as great a miracle as human imagination can easily conceive.

When they formed this design, either they must have hoped to succeed, or they must have foreseen that they would fail in their undertaking; and, in either case, they chose evil for its own sake. They could not, if they foresaw that they would fail, look for any thing but that contempt, disgrace, and persecution, which were then the inevitable consequences of an unsuccessful endeavour to overthrow the established religion. Nor could their prospects be brighter upon the supposition of their success. As they knew themselves to be false witnesses and impious deceivers, they could have no hopes beyond the grave; and by determining to oppose all the religious systems, superstitions, and prejudices of the age in which they lived, they wilfully exposed themselves to inevitable misery in the present life, to insult and imprisonment, to stripes and death. Nor can it be said that they might look forward to power and affluence when they should, through sufferings, have converted their countrymen; for so desirous were they of obtaining nothing but *misery* as the end of their mission, that they made their own persecution a test of the truth of their doctrines. They introduced the Master from whom they pretended to have received these doctrines, as telling them, "that they were sent forth as sheep in the midst of wolves; that they should be delivered up to councils, and scourged in synagogues; that they should be hated of all men for his name's sake; that the brother should deliver up the brother to death, and the father the child; and that he who took not up his cross and followed after him was not worthy of him." The very system of religion, therefore, which they invented and resolved to impose upon mankind, was so contrived, that the worldly prosperity of its first preachers, and even their exemption from persecution, was incompatible with its success. Had these clear predictions of the Author of that religion, under whom the apostles acted only as ministers, not been verified, all mankind must have instantly perceived that their pretence to inspiration was false, and that

Christianity was a scandalous and impudent imposture. **Miranda.** All this the apostles could not but foresee when they formed their plan for deluding the world. Hence it follows, that when they had resolved to support their pretended revelation by an appeal to forged miracles, they wilfully, and with their eyes open, exposed themselves to inevitable misery, whether they should succeed or fail in their enterprise; and that they concerted their measures so as not to admit of a possibility of recompense to themselves, either in this life or in that which is to come. But if there be a law of nature, for the reality of which we have better evidence than we have for that of others, it is, that "no man can choose misery for its *own sake*," or make the acquisition of it the ultimate end of his pursuit. The existence of other laws of nature we know by testimony and our own observation of the regularity of their effects. The existence of this law is made known to us not only by these means, but also by the still clearer and more conclusive evidence of our own consciousness.

Thus, then, do miracles force themselves upon our assent in every possible view which we can take of this interesting subject. If the testimony of the first preachers of Christianity was true, the miracles recorded in the Gospel were certainly performed, and the doctrines of our religion are derived from heaven. On the other hand, if that testimony was false, either God must have miraculously effaced from the minds of those by whom it was given all the associations formed between their sensible ideas and the words of language, or he must have endowed those men with the gift of prescience, and have impelled them to fabricate a pretended revelation for the purpose of deceiving the world, and involving themselves in certain and foreseen destruction.

The power necessary to perform the one series of these miracles may, for any thing known to us, be as great as that which would be requisite for the performance of the other; and, considered merely as exertions of preternatural power, they may seem to balance each other, and to hold the mind in a state of suspense. But when we take into consideration the different purposes for which these opposite and contending miracles were wrought, the balance is instantly destroyed. The miracles recorded in the Gospels, if real, were wrought in support of a revelation which, in the opinion of all by whom it is received, has brought to light many important truths which could not otherwise have been made known to men; and which, by the confession of its adversaries, contains the purest moral precepts by which the conduct of mankind was ever directed. The opposite series of miracles, if real, was performed to enable, and even to compel, a company of Jews, of the lowest rank and of the narrowest education, to fabricate, with the view of inevitable destruction to themselves, a consistent scheme of falsehood, and, by an appeal to forged miracles, to impose it upon the world as a revelation from heaven. The object of the former miracles is worthy of a God of infinite wisdom, goodness, and power. The object of the latter is absolutely inconsistent with wisdom and goodness, which are demonstrably the attributes of that Being by whom alone miracles can be performed. Hence it follows, that the supposition of the apostles bearing false testimony to the miracles of their Master, implies a series of deviations from the laws of nature infinitely less probable in themselves than those miracles; and therefore, by Mr Hume's maxim, we must necessarily reject the supposition of falsehood in the testimony, and admit the reality of the miracles. So true it is, that for the reality of the Gospel miracles we have evidence as convincing to the reflecting mind, as those had who were contemporary with Christ and his apostles, and witnesses to their mighty works. (H. H. H. H.)

MIRANDE, an arrondissement of the department of

Mirandola the Gers, in France, extending over 668 square miles. It comprehends eight cantons, divided into 155 communes, inhabited by 85,385 persons. The capital, a city of the same name, situated on the river Baise, is fortified, and in 1836 contained 2532 inhabitants. Long. 0. 11. E. Lat. 42. 33. N.

MIRANDOLA, a city of the duchy of Modena, in Italy. It stands in a marshy situation on the river Burana, whence a canal is carried to the Secchio. It is surrounded with walls, and has a cathedral and fifteen other churches, with about 7000 inhabitants. It was the capital of an independent duchy of the same name till the year 1710, when the last sovereign of the house of Pico ceded it to Modena for about L.100,000.

MIRECOURT, an arrondissement of the department of the Vosges, in France, 407 square miles in extent. It is divided into seven cantons, and subdivided into 143 communes, containing 72,343 inhabitants. The chief place is the city of the same name situated on the river Maudon, with, in 1836, 5684 inhabitants, who are occupied in making lace and musical instruments, especially violins and hand-organs. Long. 5. 5. E. Lat. 48. 50. N.

MIREPOIX, a city of France, in the department of the Upper Garonne and arrondissement of Pamiers. It is situated on the river Lers, in a district rich in good wine, and contains 450 houses, with 3100 inhabitants. In the neighbourhood a large quantity of jet is found, the procuring and polishing of which is said to employ one half of the population. Long. 1. 47. E. Lat. 43. 7. N.

MIRGOROD, a circle of the Russian province of Pultowa, extending in east longitude from 33. 37. to 34. 51. and in north latitude from 49. 51. to 50. 28. It is a district rich in corn, cattle, honey, wax, and fruits. The capital, of the same name, is a city situated on the river Khoral, 918 miles from St Petersburg, containing three churches, 970 houses, and 7637 inhabitants. Long. 33. 27. E. Lat. 48. 50. N.

MIRIAM. See **MARY**.

MIRROR, a name for a looking-glass, or any polished body, the use of which is to form the images of distant objects, by reflection of the rays of light.

Mirrors are either plane, convex, or concave. The plane reflect the rays of light in a direction exactly similar to that in which the latter fall upon them, and therefore represent bodies of their natural magnitude. The convex make the rays diverge much more than before reflection, and therefore greatly diminish the images of objects; whilst the concave, by collecting the rays into a focus, not only magnify objects, but burn very fiercely when exposed to the rays of the sun, and hence such specula are commonly known by the name of *burning mirrors*. See **BURNING MIRRORS**.

In ancient times mirrors were made of some kind of metal; and from a passage of the Mosaic writings we learn that those mirrors used by the Jewish women were made of brass. The Jews certainly had been taught to use that kind of mirrors by the Egyptians; and hence it is probable that brazen mirrors were the first kind used in the world. Any kind of metal, indeed, when well polished, reflects powerfully; but of all others silver reflects the most, though it has been in all countries too expensive a material for common use. Gold is also a very powerful reflector; and metals, or even wood when gilded and polished, act as burning mirrors. Polished ivory, or straw nicely plaited together, forms mirrors capable of burning, if constructed upon a large scale.

Since the invention of glass, and the application of quicksilver thereto, became generally known, it has been universally employed for such plane mirrors as are used for ornaments to houses.

MIRZAPORE, a town of Hindustan, in the province of Allahabad, and district of Chunar. It is situated at the foot of a range of hills on the south bank of the river Ganges.

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The town consists of handsome European houses and native habitations, with clusters of Hindu temples crowding the banks of the Ganges, and making a lively appearance when seen from the river. It is one of the greatest inland trading towns in Hindustan, and the *dépôt* of all the cotton from Agra and the Mahratta countries. It has also an extensive manufacture of carpets, and some iron-works. Several opulent merchants and indigo planters, both native and European, reside in the town and its vicinity. The travelling distance from Benares is thirty miles. Long. 83. 35. E. Lat. 25. 10. N.

MISADVENTURE, in common language, signifies any unlucky accident which takes place without being foreseen.

MISANTHROPY (from *μισος*, *hatred*, and *άνθρωπος*, *man*), a general dislike or aversion to man and mankind. In this sense it stands opposed to *philanthropy*, or the love of mankind.

MISCHNA, or **MISNA** (from *שנה*, *iteravit*), a part of the Jewish Talmud. The Mischna contains the text, and the Gemara, which is the second part of the Talmud, contains the commentaries; so that the Gemara is, as it were, a glossary on the Mischna.

The Mischna consists of various traditions of the Jews, and explanations of several passages of Scripture. These traditions serve as an explication of the written law, and supplement to it; they are said to have been delivered to Moses during the time of his abode on the Mount; and he is supposed to have afterwards communicated them to Aaron, to Eleazar, and to his servant Joshua, by whom they were transmitted to the seventy elders, and from them to the prophets, who communicated them to the men of the great sanhedrim, from whom the wise men of Jerusalem and Babylon received them. According to Prideaux's account, they passed from Jeremiah to Baruch, from him to Ezra, and from Ezra to the men of the great synagogue, the last of whom was Simon the Just. The latter delivered them to Antigonus of Socho, from whom they came down in regular succession to Simeon, who took our Saviour in his arms; to Gamaliel, at whose feet Paul was educated; and last of all to Rabbi Judah the Holy, who committed them to writing in the Mischna. But Dr Prideaux, rejecting this Jewish fiction, observes, that after the death of Simon the Just, about 299 years before Christ, arose the Mischnical doctors, who, by their comments and conclusions, added to the number of those traditions which had been received and allowed by Ezra and the men of the great synagogue; so that towards the middle of the second century after Christ, under the empire of Antoninus Pius, it was found necessary to commit these traditions to writing; more especially as their country had considerably suffered under Hadrian, and many of their schools had been dissolved, and their learned men cut off, and thus the usual method of preserving their traditions had failed. On this occasion Rabbi Judah, being rector of the school at Tiberias, and president of the sanhedrim in that place, undertook the work, and compiled it in six books, each consisting of several tracts, which altogether make up the number of sixty-three. (Prideaux, *Connex.* vol. ii. p. 468, 9th edit.) This learned author computes that the Mischna was composed about the 150th year of our Lord; but Dr Lightfoot says, that Rabbi Judah compiled the Mischna about the year of Christ 190, in the latter end of the reign of Commodus, or, as some compute, in the year of Christ 220. Dr Lardner is of opinion that this work could not have been finished before the year 190, or later. (*Collection of Jewish and Heathen Testimonies*, vol. i. p. 178.) Thus was formed the book called the *Mischna*, which the Jews have generally received with the greatest veneration. The original has been published with a Latin translation by Surenhusius, with notes of his own and others from the learned Maimonides, in six vols. folio, Amsterdam, 2 P

Misadventure
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Mischna.

Misde-
meanour
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Misprisions.

1698-1703. It is written in a much purer style, and is not nearly so full of dreams and visions, as the Gemara.

MISDEMEANOUR, in *Law*, signifies a crime. Every crime is a misdemeanour; yet the law has made a distinction between crimes of a higher and a lower kind; the former being denominated felonies, and the latter misdemeanours.

MISE, in law-books, is used in various senses. Thus it sometimes signifies costs or expenses; in which sense it is commonly used in entering of judgments in actions personal. It is also used to signify the issue to be tried on the grand assize; in which case, joining of the mise upon the mere right, is putting in issue between the tenant and demandant, the question as to who has the best or clearest right.

MISELAR, a mountainous island in the Eastern Seas, of an irregular form, and fifteen miles in circumference. It lies off the Bay of Tappanooly, on the west coast of Sumatra. Long. 98. 30. E. Lat. 1. 39. N.

MISENUM, or MISENUS, in *Ancient Geography*, a promontory, port, and town in Campania, situated to the southwest of Baiæ, in the *Sinus Puteolanus*. Here Augustus had a fleet, called *Classis Misenensis*, for guarding the *Mare Inferum*; as he had another at Ravenna for protecting the *Mare Superum*.

Upon this peninsula a villa was built by Caius Marius, with a degree of elegance which gave great offence to the most austere amongst the Romans, who thought it but ill suited to the character of so rough a soldier. Upon the same foundation Lucullus, the plunderer of the eastern world, erected an edifice, in comparison of which the former house was only a cottage; but even his magnificence was eclipsed by the splendour of the palace which the emperors raised upon the same spot. To these proud abodes of heroes and of monarchs, which have long been levelled to the ground, a few fishing huts and a lonely public house have succeeded; and men resort thither to tipple perhaps on the identical site where the voluptuous masters of the world quaffed Chian and Falernian wines.

MISER, a parsimonious person who is at the same time rich; or a wretch covetous to extremity, whom avarice has divested of all the charities of human nature, and rendered an enemy even to himself.

MISERICORDIA, in *Law*, is an arbitrary fine imposed on any person for an offence; it is called *miseriordia*, because the amercement ought to be but small, and less than that required by Magna Charta. If a person be outrageously amerced in a court that is not one of record, the writ called *moderata miseriordia* lies for moderating the amercement according to the nature of the fault.

MISFEASANCE, in law-books, signifies a trespass.

MISITRA, or MISTRA, a city of Greece, in the Morea, one of the largest in the peninsula. It is situated upon a wide plain, watered by two streams, and said to have been raised out of the ruins of ancient Sparta, which was two miles from the modern city. The country around was fertile, but has been neglected; and the population of the city has declined from 16,000 to 4000. It still produces some good silk, but is commonly considered as an unhealthy place.

MISNOMER, in *Law*, misnaming a person, or mistaking his name.

MISPRISIONS, a term derived from the old French, *mespris*, a neglect or contempt, are, in the acceptation of English law, generally understood to be all such high offences as are under the degree of capital, but nearly bordering thereon. It is said that a misprision is contained in every treason and felony whatsoever; and that, if the king so please, the offender may be proceeded against for the misprision only. Upon the same principle, whilst the jurisdiction of the Star Chamber subsisted, it was held that the

king might remit a prosecution for treason, and cause the delinquent to be censured in that court, merely for a high misdemeanour; as happened in the case of Roger earl of Rutland, in the 43d of Elizabeth, who was concerned in the Earl of Essex's rebellion. Misprisions are generally divided into two sorts; negative, which consist in the concealment of something which ought to be revealed; and positive, which consist in the commission of something which ought not to be done.

MISSAL, the Roman Catholic book, containing the several masses which are said on particular days. It is derived from the Latin word *missa*, which, in the ancient Christian church, signified every part of divine service.

MISSENDEN, a town of the county of Buckingham and hundred of Aylesbury, thirty-one miles from London. It is situated on the high road to Buckingham, and near to it is a mansion called Abbey House, built upon the site of a monastery of Black Nuns. The population amounted in 1801 to 1411, in 1811 to 1576, in 1821 to 1735, and in 1831 to 1827. About two miles from this place is Little Missenden, a pleasant village, containing, in 1801, 625, in 1811, 678, in 1821, 814, and in 1831, 937 inhabitants.

MISSIO, amongst the Romans, was a full discharge given to a soldier after twenty years' service, and it differed from the *exauctoratio*, which was a discharge from duty after seventeen years' service. Every soldier had a right to claim his *missio* at the end of twenty years.

MISSION, in *Theology*, denotes a power or commission to preach the gospel. Jesus Christ gave his disciples their mission in these words, "Go and teach all nations." The Catholics reproach the Protestants with this, that their ministers have no mission, as not being authorized in the exercise of their ministry, either by an uninterrupted succession from the apostles, or by miracles, or by an extraordinary proof of a vocation. But many amongst us deny that any other mission is necessary for the ministry than the talents necessary to discharge it.

MISSION is also used for an establishment of people zealous for the glory of God and the salvation of souls, and who go and preach the gospel in remote countries and among infidels. See RELIGIOUS MISSIONS.

MISSISSIPPI, one of the United States of North America, is situated between 88° 30' and 91° 50' of west longitude, and 30° 8' and 35° of north latitude. It is bounded on the north by Tennessee, on the south by the Gulf of Mexico and part of Louisiana, on the east by Alabama, and on the west by Louisiana and the River Mississippi. It is above three hundred miles in length, and one hundred and sixty miles in average breadth, containing a superficies of fifty thousand square miles. The surface of this state is diversified by a number of distinct ranges of hills of moderate elevation, besides a succession of eminences called bluffs, which in some cases approach to the river, and at other times are seen several miles from it. The bases of the Walnut Hills, Grand Gulf, Natchez, White Cliffs, and Loftus Heights, are washed by the river Mississippi. Two of these ranges divide the state nearly in its whole extent, and separate it into sectional divisions. As we recede from the river, the bluffs spread out into a kind of undulating table-land, but in many instances the richest table-lands have precipitous benches, by which they are exposed to what agriculturists technically term "washing." By this casualty the land is divided into deep ravines, and the richest parts of the state are subjected to it. In the northern part of the state, which is undulating, the soil is deep, black, and rich, and in its natural state is, to a considerable extent, covered with cane-brakes, like some of the more southern parts of the state. The north-west part of the state is agreeably variegated with hills and valleys of great fertility, and fine springs abound.

Missal
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Mississippi.

Mississippi.

In the lower parts of Mississippi, bordering on the river, rocks, stones of any size, and even gravel, are seldom seen above ground. The whole western limit of this state is washed by the river Mississippi, which has here a remarkably circuitous course. The flat margin of the river on this side is less valuable than similar soil upon the opposite bank. It is an inundated swamp, thinly inhabited, and covered with dense forests.

The most considerable river whose course is wholly confined to the state is the Yazoo. It rises near the limits of Tennessee, and, taking a north-westerly course, flows through a high, pleasant, and salubrious country, which, however, is chiefly claimed and inhabited by Indians. There is a fine building stone on this river, in situations favourable for conveyance to New Orleans. The next in importance is the Pearl, which is navigable for fifty miles. The Pascagoula, which has a course of two hundred and fifty miles before it falls into the Gulf of Mexico, is likewise capable of considerable navigation. The Big Black, which, measuring its meanders, has a course of two hundred miles, is navigable for fifty miles. It enters the Mississippi just above the Grand Gulf. The Homochitto is also a considerable stream, but the other rivers and creeks are comparatively small.

The climate of Mississippi is thus adapted to the growth of cotton. It is mild, and in some parts delightful; but the state being exposed to the winds of the north-west, the winters are occasionally severe, though very irregular in point of temperature. From the swampy nature of the western border, this part of Mississippi is not very healthy; the other parts, however, are salubrious. A considerable portion of this state still remains in its primitive condition, and is covered with thick forests of oak, hickory, lime, sassafras, cotton-wood, magnolia, poplar, and other valuable trees; and the swamps abound with cypress. Almost

all kinds of grain, fruits, and vegetables can be cultivated. The sugar-cane has hitherto been attempted only upon its southern frontier. The sweet orange is raised in some parts, and in the middle regions figs, grapes, and other fruits arrive at full perfection. But the grand staple of the state is cotton, and hitherto it has been found more profitable than any other production, although its price has diminished nearly two thirds within these few years. Most of the respectable farmers raise Indian corn enough to meet their own consumption, and also rear hogs sufficient to supply them with bacon.

When Mississippi was admitted into the Union in 1817, the government agreed that, after paying a debt of 1,250,000 dollars to Georgia, and indemnifying certain claimants, five per cent. of the net proceeds of the public lands lying within the state shall be applied to the formation of roads and canals. To facilitate this end several privileges were granted, such as exemption of the public lands from taxation; and in 1829 a board of internal improvement was formed, for the purpose of carrying the views of government into effect. In consequence of this arrangement, a number of railways and canals have been constructed, or are in progress. Ample public funds have also been set apart for the endowment of schools, but education is not very generally diffused, as the legislature has not enforced the establishment and support of suitable schools. An institution called a college has been incorporated at Shieldsborough, and another, called Jefferson College, at Washington, near Natchez. Besides these, there are a few flourishing seminaries of education in the principal towns. The religious bodies in this state are Methodists, Baptists, Presbyterians, Roman Catholics, and Episcopalians. The following is a tabular view of the population of the counties and county towns, according to the census of 1830.

Mississippi.

Counties.	Population.	County Towns.	Distance in miles from	
			Jackson.	Washington.
Adams, S. W.....	12,129 }	Natchez.....	112	1146
Natchez city.....	2,790 }	Liberty.....	122	1156
Amité, S. W.....	7,943	Port Gibson.....	67	1101
Claiborne, W.....	9,818	Gallatin.....	53	1087
Copiah, S. W. M.....	7,024	Williamsburgh.....	83	1087
Covington, S. M.....	2,549	Meadville.....	105	1139
Franklin, S. M.....	4,622	Leaksville.....	171	1046
Greene, S. E.....	1,849	Pearlington.....	200	1135
Hancock, S.....	1,961	JACKSON.....		1035
Hinds, M.....	8,619 }	Raymond.....	19	1053
Jackson, S. E.....	1,789	Jackson, C. H.....	213	1073
Jefferson, S. W.....	9,755	Fayette.....	93	1127
Jones, S. M.....	1,471	Ellisville.....	134	1054
Lawrence, S. M.....	5,321	Monticello.....	88	1120
Lowndes.....	3,342	Columbus.....	134	900
Madison, E.....	4,973	Livingston.....	31	1066
Marion, S.....	3,701	Columbia.....	120	1097
Monroe, E.....	3,855	Hamilton.....	150	916
Perry, S. E.....	2,285	Augusta.....	137	1063
Pike, S.....	5,402	Holmesville.....	151	1128
Rankin, W.....	2,084	Brandon.....	16	1051
Simpson, S. M.....	2,666	Westville.....	56	1090
Warren, W.....	7,861	Vicksburgh.....	54	1089
Washington.....	1,976	Princeton.....	119	1154
Wayne, E.....	2,778	Winchester.....	165	1008
Wilkinson, S. W.....	11,693	Woodville.....	148	1182
Yazoo, W.....	6,550	Benton.....	64	1075
Total population in 1830....	136,806, of whom 65,659 were slaves.			

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Natchez is much the largest town, and the principal seat of commercial transactions. It is romantically situated on the east bank of the river Mississippi, on a very high bluff, about two hundred and eighty miles above New Orleans, in long. $91^{\circ} 25'$ west, and lat. $31^{\circ} 34'$ north. It is the principal town in this region for the shipment of cotton to New Orleans. Great numbers of boats are always lying here, and in the autumn and winter Natchez presents an animated and bustling aspect, but in summer little business is transacted. The streets are broad; many of the buildings are in very good style, and the whole has the appearance of cleanliness, comfort, and opulence. The Bank of the State of Mississippi, a United States' Branch Bank, and the Planters' Branch Bank, are at Natchez. The first has a capital of one million, and the last a capital of three millions of dollars.

Monticello is a flourishing village situated on Pearl River, and was some years ago the seat of government; but Jackson, near the head of the same stream, is now the political metropolis. It has a central, healthy, and pleasant situation, but the inhabitants are not numerous. Vicksburgh, below the Walnut Hills, on the Mississippi, has risen up within these few years, and has already become a place of great trade. Gibson Post, which is situated on Bayou Pierre, about thirty-five miles above Natchez, is a village of considerable importance. Shieldsborough, Greenville, Woodville, Winchester, Washington, and Warrenton, are also flourishing places.

On the 1st of January 1832, the unsold lands, to which the Indian and the foreign titles had been extinguished, amounted to 21,211,465 acres. At the same date the Indians still claimed 6,529,280 acres, and 733,244 acres had been set apart for the erection of schools and for government purposes. The manufactures and shipping of this state are too unimportant to require particular mention. In 1836 there were in Mississippi five banks, to which a number of branches were attached. Printing was introduced about the beginning of the present century, and in 1834 thirteen newspapers were published within the state.

Mississippi was admitted into the Union in 1817. The constitution and laws bear a common resemblance to those of the other states. The legislative body is styled a general assembly, consisting of a senate which is elected triennially, and a house of representatives which is elected annually. The rights of citizenship are enjoyed by those who have a freehold or an interest in real estate. The governor serves two years, and is eligible only four years out of six. The judiciary consists of a supreme and circuit court, together with subordinate courts appointed by the legislature. The judges are appointed by the legislature, and hold their offices during good behaviour. The state is divided into seven circuits or districts, and one judge and a district attorney are chosen by the electors of each district; and a circuit court is held in each county twice every year. This court has original jurisdiction in civil causes, in which the sum in controversy exceeds fifty dollars. All persons above twenty-one years of age, and citizens of the United States, are electors.

A great number of Indians still hold possession of considerable tracts of country in this state. The principal tribes are the Chactaws and Chickasaws, the number of the former being estimated at 20,000, and that of the latter at about 4000. They are at present in a semi-savage state; but many of them have good houses, slaves, enclosures, and cattle. Schools have been established amongst them for the reception of Indian pupils, and there are missionary stations whence the truths of Christianity are diffused over the country.

VALLEY OF THE MISSISSIPPI.—This name has been given to the vast tract of country which is watered by the Mississippi river and its numerous tributary streams, and which

is included between the Alleghany and the Rocky Mountains. Mr Flint, in his volume descriptive of this large and important part of North America, also includes in it those portions which are watered by the comparatively small rivers Mobile, Pearl, and others of West Florida on the east side, and the Sabine, Brassas, and Colorado of Texas on the west side. If we include the minor valleys traversed by these streams, the great valley of the Mississippi is bounded on the south by the Gulf of Mexico, and extends on the south-east to Cape Florida. Running along that cape in a northerly direction, the boundary on the east passes those table elevations which separate the waters of the Mobile and Tombigbee from those of the rivers of East Florida; thence it proceeds through what has been designated the country of the Indian nations, and touching the north-western extremity of Georgia, it reaches the Alleghany Mountains, which constitute the eastern boundary. On the north no mountain ridges indicate the line of demarcation between this valley and the basins of the lakes, or between the waters of the Mississippi, and those which flow northward into Lake Winnipeg, Hudson's Bay, and the Arctic Ocean; but the valley is generally considered as terminating on the north where it begins to receive its waters. The Rocky Mountains define the western boundary; and one of the southern ridges of this chain divides the waters of Arkansas and Red Rivers from those of the Rio del Norte, and traverses Coahuila and Texas to the low grounds on the Gulf of Mexico. The valley of the Mississippi thus stretches over twenty degrees of latitude, exclusive of Cape Florida, and about thirty degrees of longitude.

No other valley on the globe, with the exception of that which is drained by the river Amazon, can be compared in extent with that of the Mississippi; and it probably surpasses all others in the richness and variety of its soil, and in its general adaptation to the support and comfort of civilized men. In extent it resembles a continent; and in beauty and fertility it is the most perfect garden of nature. It is, however, unnecessary to enter into a particular account of it as a whole, the individual states into which it is divided being all described separately. The history of its settlement, although interesting, would stretch this article to an unreasonable length. It is given generally in that on AMERICA, to which the reader is referred; and also more particularly under the heads of the various states embraced within the limits of the great valley.

MISSISSIPPI RIVER.—This river is the largest in the United States, and also one of the largest in the world. Until the year 1832, when an expedition to ascertain its source was undertaken by order of Congress, it was unknown in our geography, that above Cass Lake the Mississippi separates into two forks, and that it derives its origin from Itasca Lake, which is situated 182 miles above Cass Lake. This is a beautiful sheet of water, seven or eight miles in extent, and lying amongst hills of diluvial formation, surmounted with pines. The outlet of Itasca Lake is about ten or twelve feet broad, but of little depth. The Mississippi is considered as originating at an altitude of 1500 feet above the Atlantic, in latitude 48° north, and longitude 96° west. Its length is about 3160 miles, and it falls into the Gulf of Mexico at Balize, in latitude $29^{\circ} 6'$, and longitude $89^{\circ} 30'$. Its general course in ascending above Cass Lake is north of west as far as Lac Travers; then south to its primary forks, which is continued, following up the east fork to Kubbakunna Lake, and for some distance farther. It then varies a short distance north and north-west, then south-west and south; and, finally, south-west to its main source in Ussawa Lake. The portage thence to Itasca Lake is west-south-west. Both these lakes appear to rise in springs on the high ground, and they are separated by about six miles of country. The Mississippi

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traverses more degrees of latitude than any other river in America, and consequently the varieties of climate and vegetable productions which it passes through are very great. It occupies about a thousand miles of the distance between the arctic circle and the equator. Long as it is, however, the Mississippi has a tributary longer than itself, the Missouri. Like the Niger, its mouth was discovered by navigating down its current; but, unlike that stream, which so long held the geographical world in suspense, its sources have also been sought from its central parts. Its entire course has at length been ascertained; and we may now appeal with full certainty to the Balize and to Itasca Lake as its extreme points. At the latter it is a placid basin of transparent spring water; at the former it is as turbid as the earth which it holds in suspension can make it, and carries forests of floating trees on its turbulent bosom. Below the junction of its primary forks it expands at very unequal distances into eight sheets of clear water, each of which possesses features worthy of admiration. Four of these, Lac Travers, Cass Lake, Winnipeg, and Lake Pepin, are lakes of respectable magnitude and striking scenery. The broadest parts of its channel lie in the central parts of the valley of the Mississippi. Its depth is great in all its lower parts, and increases as it flows on to the gulf, and its general descent and velocity are such as to appear very striking characteristics. We are not aware that it has been sounded in such a manner as to justify any estimate of its average depth. At Natchez, about 400 miles from its mouth, it has been stated to be from 100 to 150 feet deep, and this increases the lower we descend. From the Falls of St Anthony, to a few miles below the river Des Moines, in latitude 40°, the Mississippi is about half a mile broad. Below the rapids which occur at this place its average breadth is about a mile; its current is about two miles an hour, and its average depth about four feet. Where it receives the Missouri, it is a mile and a half wide. The mouth of the Missouri is about half a mile wide, and when these are united, they constitute a stream about three quarters of a mile in breadth, very deep, and having a furious boiling current. The medium current is about four miles an hour, but it is often much greater. Its average width during the remainder of its course does not exceed a mile. In estimating its breadth, we refer to the space between the banks of its regular channel. At every flood it overspreads a vast tract of country, principally on its western side, which is from ten to fifty miles in breadth through the last five hundred miles of its course; and most of the water which overflows below Red River goes to the Gulf of Mexico without returning to the river. The country thus overflowed is generally without any habitable spots, but is covered with cypress, cotton-wood, or coarse grass, and its waters abound with alligators. The number of the tributaries of the first, second, and third class, is so great that it would form a labour of some research to determine it. The Missouri, the Ohio, the Red River, and the Arkansas, are of the noblest order. The first-named stream flows in a little below 39°, the Ohio between 37° and 36°, the Arkansas between 34° and 33°, and the Red River a little below 31°. Below the latter river there are many large outlets, but no considerable streams join the Mississippi. After receiving the Missouri, the course of this great river is so serpentine as to present very few "reaches," or places where it is so straight that an extent of three or four miles can be seen at one time. In many places the low alluvial tract upon its borders is thirty or forty miles in breadth. From the sources of the river to the mouth of the Missouri the annual flood ordinarily commences in March, and does not subside till the end of May; and its medium height is fifteen feet. Between the Missouri and the mouth of the Ohio the annual flood is twenty-five feet. For a great distance be-

low this point it is fifty feet; but it subsides above Natchez, and thence gradually to the mouth of the river. Between the Missouri and the Ohio the most shallow parts of the channel have six feet of water when it is lowest. Thence to the St Francis, between latitude 35° and 34°, there are several shoal places, where, when the water is low, pilots are perplexed to find a proper depth. Below that point there is no difficulty for vessels of any draught, except to find and preserve the right channel. There are no tides in the Mississippi, although a variation of a few inches in the height of the water is sometimes observed both during the day and night; but even at the very mouth of the river the water is at all times fresh, and no ebb and flow corresponding with those of the ocean are observed. Its navigation is at all times attended with some danger, on account of the raging power of the current, and the numerous trees which it dislodges on its banks and bears away in its course. Steam-boats, however, are admirably fitted to avoid these dangers; and the navigation above New Orleans is every year becoming more and more confined to them. Flat boats still bring down much produce, but almost no other vessels besides steam-boats are seen ascending the river.

(R. R. R.)

MISSOURI, one of the United States of North America, is situated between 88° 17' and 94° 30' of west longitude, and 36° and 40° 30' of north latitude. It is 270 miles in length by 220 in breadth, and contains an area of about 60,000 square miles. It is bounded on the north and west by the Missouri territory; on the east and north-east by the Mississippi, which separates it from Illinois; on the south-east by the Mississippi, which separates it in this quarter from Kentucky and Tennessee; and on the south by Arkansas territory.

A large portion of this state, situated in the south-east quarter, is low, swampy, full of lakes, and in many places liable to inundation. Beyond this region, which is generally marked by a bold line of rolling and fertile high lands, the country gradually becomes mountainous, and continues so to the Osage and its tributaries. It then becomes broken and hilly, until it opens upon the boundless belt of prairies which spreads beyond the western limits of the state. The best land is situated between the Missouri and the Mississippi; and no part of this vast tract is mountainous, consisting chiefly of alluvial and hilly prairies of a very rich soil. The importance of large navigable rivers to a civilized and commercial people is well known; and no quarter of the globe is so amply provided in this respect as Missouri, the greater part of rich and easily cultivated soil stretching along the banks of majestic streams. The Mississippi sweeps along its eastern border 550 miles, receiving in its course the great river from which the state derives its name. The Missouri, entering the western boundary, traverses the state, receiving on either side tributaries, which, if not contrasted with the stream into which they empty their waters, would deserve the title of fine rivers. The Osage, rising in the angle between Arkansas and Kansas Rivers, on the vast plains west from the state of Missouri, carries its serpentine but navigable volume into Missouri River, near the centre of the state. The St Francis and White Rivers rise in this state, and flowing southward, connect it with the Arkansas. A great many large and beautiful rivers enter the Missouri as tributaries. Some of these have a course in the state, but most of them belong to the territory of Missouri.

The soil of this state is as varied as the surface, every quality being found, from the most productive and inexhaustible alluvium, to tracts of sterile clay or siliceous sand. According to Mr Flint, there is a specific difference between the alluvium of the two rivers Mississippi and Missouri; the bottoms of the latter being more loamy and sandy, and those of its rival more clayey and sub-

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Missouri. stantial. On the eastern border, and near the streams generally, a dense forest covered Missouri; although in some parts naked prairie encroaches upon the streams. Speaking in general terms, the south-east section is alluvial, and liable to a partial annual inundation; the south-western is mixed prairie and "flint hill" land; the northern section, west from the Mississippi and north from the Missouri, contains, as we have already said, the choicest land in the state. The soil of the upland prairies is far inferior to that of the alluvial prairies. Upon the whole, the good lands of this country have in general a great degree of fertility; and there is scarcely any part sufficiently level for cultivation which does not produce good crops of corn without manure, whilst in many instances the poorer lands are found to be better for wheat than the richer. The prairies are in general level, and of an intermediate character between the richer and poorer uplands; and the bottoms of all the water-courses are rich. The geographical extent of Missouri, and its great diversity of soil, admit of a corresponding variety of vegetable productions. Wheat and Indian corn have been the staples of this state during the comparatively short period that any part of it has been cultivated. Its soil also produces the other kinds of grain in perfection. Cotton is raised in the south-eastern section; tobacco thrives well; and flax and hemp are likely to become largely cultivated. Turnips and bulbous-rooted vegetables grow to a great size. Pumpkins, squashes, and melons, are nowhere raised in greater abundance; and sweet as well as Irish potatoes thrive sufficiently well. Cultivated grasses have hitherto not succeeded so well as the other articles of culture. At present the fodder provided for the stable in winter is chiefly corn, its leaves and husks, with what is called prairie grass. This is a coarse and tall grass, covering the prairies in the greatest abundance. All the fruits of the northern and middle states thrive in an uncommon degree. Three species of vine are common in all parts of the country; whilst the warmth of summer, and the dryness of the atmosphere, peculiarly fit this state for the cultivation of the medicinal plants, rhubarb, palma Christi, and the poppy. Indeed many parts of it are likely to rival the best tracts east of the Mississippi in the abundance of their productions. "This state," says Mr Flint, "has lands already, fit for the plough, sufficient to produce wheat enough for the whole United States. Prairies of hundreds of thousands of acres of first-rate wheat-lands, covered with grass, and perfectly free from shrubs and bushes, invite the plough; and if the country were cultivated to a proper extent it might become the granary of the world." "Above all countries," says the same writer, "this is the land of flowers. In the season, every prairie is an immense flower garden. In the early stages of spring rises a generation of flowers, whose prevalent tint is peach-blossom; the next is a deeper red; then succeeds the yellow, and to the latest period of autumn the prairies exhibit a brilliant golden hue." Agriculture in all its forms, either as an art or as a science, is yet in its infancy in Missouri, as it may be supposed to be in any newly-settled country where nature has done so much. The climate is extremely fickle and variable, and the changes of temperature are very great. During three winters in five the Mississippi is passable on the ice at St Louis. Receding from the Atlantic, it is in this state that the frigid winds of the north-west are first experienced in all their force. The prevailing winds follow the direction of the Mississippi Valley; those from the northward are cold, but the southern winds are warm. The winter commences about Christmas, and is frequently severe; but the summers are very warm, and as the country is bare, and open to the sun's influence, whilst the soil is of a warm and sandy texture, calculated to admit the solar rays, a great quantity of caloric is imbibed. Less rain falls here than in New England, or the southern states, and the atmosphere is much drier and more bracing. It is, however, cold and windy; but successive years vary so much that a general rule can scarcely be laid down. Uncertain as are the revolutions in meteorology elsewhere, they are proverbially variable in the state of Missouri and the adjacent regions. In regard to health, this state has a somewhat suspicious character; but in course of time, by cultivation, draining, and similar operations, it is likely to become as salubrious as any other in the Union. Although but a few years since a tenement in any degree superior to a temporary log-hut was a very rare object, the progress of civilization is marked by the rapid disappearance of those primitive structures, and the substitution of brick and stone houses. Bears, wolves, panthers, buffaloes, elks, deer, the mole called gopher, the bite of which is said to be poisonous, the prairie dog, rattle snakes, and other reptiles, are found in this state. Great varieties of water-game swarm on the lakes, ponds, and rivers during certain seasons of the year. Generally speaking, the hunter will find in no country a finer field for his pursuits. The domestic animals are the same as in other parts of the United States.

Missouri is rich in minerals and metals, and it has become celebrated for immense deposits of lead ore, chiefly of galena. It is dug out in various parts of the state; but there is a district extending nearly a hundred miles in length and forty in width, which is particularly distinguished for its lead mines. The centre of the district is about seventy miles south-west from St Louis, and about half as far from Herculaneum on the Mississippi. The ore is found in imbedded masses, and appears evidently to be a deposit. Coal in immense strata also exists in Missouri, and iron ore forms no inconsiderable part of many of the hills. The other minerals discovered are plaster, manganese, zinc, antimony, cobalt, various kinds of ochre, common salt, nitre, plumbago, porphyry, jasper, calcedony, and marble. There are as yet but few public roads, although Congress has paid attention to the construction of railways and other public works. A railroad from Marion city to Palmyra has been commenced; and it is intended to continue it to New York, the capital of Shelby county, and thence to the Missouri, near Chariton. Another has been projected extending from St Louis to Fayette, upwards of a hundred miles in length; and another leading from St Louis to the lead mines in Washington and Franklin counties. With a few exceptions, the habitable parts of Missouri constitute one vast plain, so that roads are easily constructed, and those which have been made are remarkably good, and passable at all seasons of the year. In 1825, commissioners of the United States laid out a road through the wilderness, leading from Missouri to Mexico; and the Osages, by treaty, in consideration of 800 dollars, granted the right of making and using the road through their lands.

In reference to trade, it is not to be supposed that Missouri, so recently settled, can have much, excepting in such articles as are immediately supplied by nature. Accordingly, lead and fur constitute the staples of commerce. The lead annually smelted exceeds three millions of pounds, a considerable quantity certainly, but nothing compared with what might readily be obtained. There is doubtless ore enough of the best quality to supply the whole world with lead. The commerce in this article, therefore, is likely to increase rapidly; for the mines are rich, and the part of the country in which they are situated is remarkable for its salubrity, as well as for the fertility of its soil, and its fine streams. Shot-towers are erected at Herculaneum and other places; and great quantities of shot are exported. St Louis is the centre of the fur trade. Boats are continually passing between this town and New

Missouri. Orleans. Since Mexico achieved its independence, considerable commercial intercourse has been established with the interior provinces of that republic, by means of the road above mentioned. Amongst other companies incorporated by the legislature within these few years are, the Missouri Insurance Company, capital one hundred thousand dollars, and the privilege to increase it to four hundred thousand; the St Louis Marine Railway Company; the St Louis Hospital; the St Louis Water-Works; and the St Louis Marine and Fire Insurance Company. The bank of the United States has an office of discount and deposit at St Louis. There are various other companies established throughout the state, amongst which may be mentioned an iron foundry on a respectable scale in the vicinity of St Louis, and one or two large establishments at Bellevue, in the mine country, which smelt their own iron from mines in the immediate vicinity.

The most numerous denominations of Christians in Missouri are Methodists, Presbyterians, and Catholics. Accord-

ing to the American Almanac for the year 1837, the United Brethren or Moravians had thirty-three ministers, twenty-four churches or congregations, and two thousand communicants; whilst the Catholics had thirty-nine ministers. Religious instruction and good schools are less esteemed and less common in this new state than in most others in the Union. St Louis College, a Catholic institution, was founded in 1829: in 1836 there were fifteen instructors, nine alumni, two hundred students, and 7500 volumes in the library attached to it. Corporations have been formed for a number of academies, colleges, and seminaries of education; and the legislature has passed an enactment to sell all the lands appropriated to the interests of education, and apply the funds thence arising to the purpose for which it was intended. There are a number of convents in the state, to which young females are sent to be educated. In 1810 there was only one newspaper in the state, but in 1836 the number had increased to fifteen.

Missouri.

Population of the Counties and County Towns in 1830.

Counties.	Population.	County Towns.	Distance from	
			Jefferson City.	Washington.
Boone.....	8,829	Columbia.....	56	891
Callaway.....	6,102	Fulton.....	32	967
Cape Girardeau.....	7,430	Jackson.....	208	856
Chariton.....	1,776	Chariton.....	79	1031
Clay.....	5,342	Liberty.....	190	1142
Cole.....	3,006	Jefferson City.....		980
Cooper.....	6,019	Booneville.....	51	1023
Crawford.....	1,709	Little Piney.....	98	989
Franklin.....	3,484	Union.....	79	901
Gasconade.....	1,548	Gasconade.....	47	939
Howard.....	10,844	Fayette.....	65	1017
Jackson.....	2,822	Independence.....	177	1129
Jefferson.....	2,586	Herculaneum.....	164	886
Lafayette.....	2,921	Lexington.....	138	1090
Lincoln.....	4,060	Troy.....	97	913
Madison.....	2,371	Fredericktown.....	170	894
Marion.....	4,839	Palmyra.....	190	984
Monroe.....		Monroe.....	129	998
Montgomery.....	3,900	Lewistown.....	67	932
New Madrid.....	2,351	New Madrid.....	278	892
Perry.....	3,377	Perryville.....	187	882
Pike.....	6,122	Bowling Green.....	132	948
Ralls.....	4,346	New London.....	167	961
Randolph.....	2,962	Randolph.....	96	1042
Ray.....	2,657	Richmond.....	149	1101
St Charles.....	4,322	St Charles.....	123	876
St Françoise.....	2,386	Farmington.....	152	912
St Genevieve.....	2,182	St Genevieve.....	168	874
St Louis.....	14,907	St Louis.....	134	856
Saline.....	2,893	Walnut Farm.....	85	1038
Scott.....	2,136	Benton.....	236	861
Washington.....	6,797	Potosi.....	127	915
Wayne.....	3,254	Greenville.....	200	908
Total population....	140,074			

Of this population 24,990 are slaves. In 1836 it was estimated at 210,000, being an increase of 70,000 in less than six years.

The commercial capital of Missouri, and the principal town west of the Mississippi, is St Louis. It is situated on the western bank of the above-named river, eighteen miles by water below the junction of the Missouri, fourteen above that of the Maramac, thirty below that of the Illinois, and 200 above that of the Ohio, being in long. 89.36. W., and lat.

38. 36. N. The situation of the town is elevated, pleasant, healthy, and admirably adapted for commerce. The ground upon which it stands rises gradually from the first to the second bank, which is forty feet above the place upon which St Louis is chiefly built. On this bank are the fortifications erected in early times for the defence of the place.

Missouri. The town extends two miles along the river, in three parallel streets, which are intersected by others crossing them at right angles. It contains several places of public worship, amongst which is a Catholic cathedral. It has also a spacious town-house, a theatre, a land office, a bank, a museum, two or three printing offices, a brewery, and several mills. Many of the houses are built of stone, but not a few are entirely constructed of wood. It is in a state of rapid improvement, and fast increasing in population and trade. Its situation is advantageous and interesting, being more central with regard to the whole territory belonging to the United States than any other considerable town; and, uniting the advantages of the three great rivers Mississippi, Missouri, and Illinois, with their numerous branches, whilst it possesses unrivalled facilities for trade, it will in all likelihood become a great city, and the centre of a very extensive commerce. An idea of the present state of the trade of St Louis, and the rate at which it increases, may be formed from the following abstract made from the steam-boat register.

	1831.	1835.
Number of different boats arrived.....	60.....	121
Number of arrivals.....	532.....	803
Aggregate amount of tonnage.....	7769...	15,470

The country around and to the west of St Louis, for a distance of fifteen miles, is an extended prairie of a very luxuriant soil. This town was settled, principally by French emigrants from Kaskaskias, soon after the peace of 1763, when France ceded to Great Britain her right to all the country eastward of the Mississippi. It came to the United States by the cession of Louisiana in 1803. The population at that time was below 1000; in 1830 it had risen to 5852; and at present (1837), judging from the increase of trade, it cannot amount to less than 10,000 or 12,000.

The other towns in the state of Missouri are, with a few exceptions, of but small size and little importance. *Herculanum* is situated on the western bank of the Mississippi, thirty miles below St Louis, upon a narrow alluvial plain, hemmed in on all sides but that facing the river by high and romantic bluffs, rendered still more imposing by a number of shot-towers planted on their summits. This is the chief place of deposit for the lead of the lead mines. *St Genevieve* is situated at the upper extremity of a beautiful alluvial prairie about a mile westward of the Mississippi. The town is finely situated, and has some trade, most of the lead for exportation being brought to it. The population amounts to about 1500. *New Madrid* is situated on the Mississippi, about fifty miles below the mouth of the Ohio. Next to *Natchez*, it is the most noted landing place for steam-boats on the Mississippi above New Orleans. It is chiefly deserving of mention from having, along with the country around it, been visited, in 1811 and the following year, by two of the most terrible and destructive earthquakes which ever laid waste the works of man and nature. *Jefferson*, a new town above the mouth of the Osage, on the south side of the Missouri, has become, since the seat of government was removed there, the position of the public buildings; but not being a fortunate selection, it has not greatly prospered. *Franklin* is situated on the northern bank of the Missouri, 150 miles by land above St Louis. It is estimated to contain above 200 houses, and about 1200 inhabitants. It is surrounded by the largest body of rich land in the state, and is the centre of a populous region of opulent and respectable farmers. *Potosi*, the county town of Washington, is the centre of the mine district. It is situated in a pleasant valley surrounded by hills, sixty-five miles south-west from St Louis. *St Michael* is an old French village amongst the mines, and there are a number of other small villages in the same district. *St Charles*, on the Missouri, is a pleasant village, containing about 1200 inhabitants. It was for a number of years

the political metropolis of the state; and no place in the western territory has a more interesting country adjoining it than this village. The other places are too small to require particular description.

This state adopted its present constitution, and was admitted into the Union, in 1820. In its general features it resembles those of the other states. The senators are elected for four years, and the representatives for two. The governor is elected for four years. The judicial power is vested in a supreme court, a chancellor's court, and circuit, and other subordinate courts, the judges of which hold their offices during good behaviour. Every free citizen who has resided a year in the state, and the last three months preceding the election in the district, is entitled to a vote in that district. The legislature meets at *Jefferson* every second year, on the first Monday of November. The article which allowed the existence of slavery in the state was long and bitterly contested in the national legislature; but the admirers of the whip and chain prevailed. There is nothing either interesting or remarkable in the history of Missouri. It formed a part of the extensive country of Louisiana which was purchased from France by the United States in the year 1803. Although French settlements were commenced at *St Louis* and *St Genevieve* as early as 1764, yet, at the time when the country was purchased, this portion of it contained but few inhabitants. In 1804 this country was separated from the rest of Louisiana, and erected into a territorial government by the name of the Territory of Louisiana, which was afterwards altered to the Territory of Missouri, and lastly to the State of Missouri. Immigration at first proceeded rapidly, but received a check in the year 1811 from the sickness of the season; and the late war also effectually repressed for a time the increase of the country. In 1817 various causes conspired to retard the advancement of this state. Improvements of every description not only came to a dead pause, but seemed to retrograde. This continued for several years; but in the year 1824 prosperity advanced anew, the tide of immigration once more set towards Missouri, and it has ever since continued to improve.

MISSOURI TERRITORY, a tract of country belonging to the United States, which is bounded on the north by the British possessions, on the east by the North-west Territory, Illinois and Missouri, on the south and south-west by the territories of the Mexican republic, and on the west by the Rocky Mountains. It is 900 miles in length by 800 in breadth. The belt of land on the western bank of the Mississippi, which is partially wooded, is generally from 200 to 400 in breadth. Then commence the vast prairies which constitute so striking and impressive a feature in the immense country stretching beyond the Mississippi and the Missouri. It is for the most part a plain, more or less covered with grass, and in many places fertile; but in others it presents only an ocean of moving sand. Countless multitudes of buffaloes, elks, and other wild animals, graze upon it. The principal sources of the Missouri, Arkansas, and Red River, are found in this territory; and several large branches of the Mississippi, above the Missouri, come from the north-western part of the same vast country. Of the Rocky Mountains, which are as yet but imperfectly known, Mr Flint, in his *Geography of America*, gives the following account.

"The Rocky Mountains commence in the unexplored regions to the north-west of the United States, and, ranging across the sources of the Missouri, the Roche Jaune, Platte, Arkansas, and Red River, in the Mexican states of Texas and Coahuila, they diverge and unite with the ranges of Mexican mountains. They separate the waters of the great tributaries of the Mississippi from those that fall into the Columbia or Multnomah, the great lake of *Buenaventura*, and other waters of the Pacific. They

Missouri. have a far greater extent than the Alleghany Mountains, are of a wider range, and for the most part run, like them, in parallel ridges, though generally more ragged, detached, and broken, and are by no means so regular. They are also of a character decidedly more primitive. Their black, precipitous, and frowning appearance has probably given them the name of the Rocky Mountains. Their bases have an elevation of between 3000 and 4000 feet above the level of the sea. James's or Pike's Mountain has been given as about 12,000 feet in height. As this vast range of mountains is as yet but very imperfectly known, there is little reason to doubt that many of the peaks, when more fully explored and more accurately measured, will be found to approach much nearer in height to the highest ranges in Mexico than has been commonly supposed. Most of the more elevated summits are above the limit of perpetual congelation. In one respect they resemble the Alleghanies. In numerous places the waters that run into the Pacific rise near those that fall into the tributaries of the Mississippi. Thus has nature kindly provided points of easy transit from the eastern to the western side of these frowning and apparently impassable barriers of nature. By communications of unquestionable veracity, from persons engaged in the Missouri Fur Company, we learn that, following up the valleys of the sources of the Platte to the opposite valleys of waters that fall into the Great Lake of Buenaventura, on the other side, a good road was found, and easily passable by loaded waggons." This vast inland sea is one hundred miles in length by from sixty to eighty in breadth, and its waters are much salter than those of the ocean.

There are other ranges of mountains, which traverse different parts of this territory; as the Black Hills, the Ozark Mountains, the Masserne, and others. There are also fertile belts of land on the margins of most of the rivers, and some of them have a great extent of rich country. As we recede from the rivers, the soil becomes poor, and extensive deserts are found in the southern regions. In such a vast extent of level country, naked and open, the climate must of course in a great measure depend upon latitude. Immediately beyond the state of Missouri and the Arkansas territory, the climate is mild and temperate; but it gradually becomes similar to that of Canada. There are very few settlements of whites in this vast country, and none so considerable as to have any established government. At Council Bluffs there is a military post, having one regiment of infantry. Many tribes of Indians still possess vast tracts of country. The Sioux are the most numerous; and the whole number has been estimated at about 140,000.

MISSOURI, a very large river of the United States, which unites with the Mississippi a little beyond the thirtieth degree of north lat. It originates in the Rocky Mountains, and takes the name of Missouri in lat. 45. 10. north, and in long. 110. west, where the three branches, Jefferson, Galatin, and Madison unite. These head branches of the Missouri are navigable to a considerable extent before their junction. Where the river makes its escape from the Rocky Mountains, it presents a spectacle of rare sublimity. For a distance of about six miles the rocks rise 1200 feet perpendicularly from the water's edge. The river is considerably diminished in width where it rushes through these gates of the Rocky Mountains. One hundred and ten miles below this chasm are the stupendous cataracts of the Missouri, one of which has a perpendicular fall of eighty-seven feet, but according to Mr Flint of ninety-eight feet. For about seventeen miles the river may be termed a series of cataracts. Not far below these falls Maria's River from the north joins the Missouri. It is a considerable stream, as are also the Dearborn, Fancy, Manoles, Big Dry, and others, which enter still farther down. Below

these the Missouri receives the waters of the Roche Jaune or Yellow Stone, probably its largest tributary. It rises in the same ranges of mountains as the main river, and in many respects resembles it. It is a broad, deep, and sweeping stream, and at its junction appears to be the larger of the two, entering from the south by a mouth of 850 yards wide. Its course is commonly calculated at 1600 miles, and its entrance is said to be 1880 miles above the mouth of the Missouri. It was selected by the government as an eligible situation for a military post and an extensive settlement. At the junction of the Yellow Stone, the Missouri has wide and fine bottoms, but unfortunately its banks are almost destitute of timber, which will retard its settlement for a long time. A great many rivers join the Missouri below this. The following are the most considerable: Knife River; Cannon-Ball River, which is 140 yards wide; Chienne, which is boatable 800 miles; Poncas, Quicourre, White Stone, Big Sioux, Floyd's, and many other streams, all enter on the south side. La Platte, which has a longer course than any tributary of the Missouri, comes in from the south side. It rises in the same ranges of mountains which give birth to the parent stream, and, measured by its meanders, is supposed to have a course of 2000 miles before it joins the principal stream. It is nearly a mile in width at its entrance; but, as its name imports, is shallow, and not boatable except at its highest flood. Kansas, a large tributary from the south, has a course of 1200 miles, and is boatable nearly the whole of its course. From the north side, the following, amongst other streams, flow into the Missouri: the Grand River, which is large, long, deep, and boatable for a great distance; the Nowada, Little Platte, Charatous, Bonne Femme, and Manitou.

The whole length of the Missouri, above its junction with the Mississippi, has been estimated at above 3100 miles. Add to this the distance from the mouth of the Missouri to the Gulf of Mexico, and the total will be nearly 4400 miles. The Missouri is much longer than the Mississippi before their junction, and has a much greater volume of water. It is about half a mile in breadth at its mouth, but is wider in a great part of its course. (R. R. R.)

MISTERBIANCO, a town of the island of Sicily, in the kingdom of Naples and the province of Demone, 118 miles from Palermo. It stands upon Mount Ætna, and is the Monasterium Album of Pirro. The situation is healthy, and the inhabitants are 3500. It is surrounded with basaltic rocks and warm baths.

MISTRETTA, a parliamentary city of the island of Sicily, in the kingdom of Naples and province of Demone, seventy-eight miles from Palermo. It stands on the north shore, near the mouth of the river Nebroden, on an elevated and healthy situation. It contains 8000 inhabitants.

MITCHAM, a village of the county of Surrey, in the hundred of Wallington, seven miles from London. It is pleasantly situated on the river Wandle, a stream remarkable for its trouts, and for the number of mills turned by it within a short distance. The population amounted in 1801 to 3466, in 1811 to 4175, in 1821 to 4453, and in 1831 to 4387.

MITCHELSTOWN, a post-town of Ireland, in the county of Cork, 132 miles south-west from Dublin. It is built on the site of an ancient town called Brighgobban, said to have been founded by a saint of whom a relic was long preserved. Lord Baron Kingston here founded an establishment called the College, where a number of decayed gentlemen and gentlewomen are comfortably provided for. The population amounted in 1831 to 3545.

MITE, a small piece of money mentioned in St Luke's Gospel (xii. 59, and xxi. 2). In the Greek it is *χοδραντς*, *quadrans*, or a quarter of the Roman *denarius*; so that the mite was worth about seven farthings, or nearly twopence of our money.

Misterbi-
anco
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Mite.

Mithras
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Mithrida-
tes.

MITHRAS, FEASTS OF, in *Antiquity*, were celebrated amongst the Romans in honour of Mithras or the Sun. The most ancient instance of this amongst the Romans occurs in an inscription dated in the third consulate of Trajan, or about the year of our era 101. This is the dedication of an altar to the Sun under the name of Mithras, and inscribed *Deo Soli Mithræ*. But the worship of Mithras was not known in Egypt and Syria in the time of Origen, who died about the year of Christ 263; although it was common at Rome for more than a century before this time. The worship of Mithras was proscribed at Rome in the year 378, by order of Gracchus, prefect of the prætorium. According to Fréret, the feasts of Mithras were derived from Chaldæa, where they had been instituted for celebrating the entrance of the Sun into the sign Taurus.

MITHRAS, or MITHRA, a god of Persia and Chaldæa, supposed to be the Sun, and whose worship was introduced at Rome. He is generally represented as a young man, whose head is covered with a turban after the manner of the Persians; and he supports his knee upon a bull lying on the ground, one of the horns of which he holds in one hand, whilst with the other he plunges a dagger in his neck.

MITHRIDATES, the name of several kings of Pontus.

MITHRIDATES, surnamed *Eupator*, and also the *Great*, succeeded to the throne at the age of eleven, about 123 years before the Christian era. The beginning of his reign was marked by ambition, cruelty, and artifice. He murdered his own mother, who had been left by his father co-heiress of the kingdom; and he fortified his constitution by drinking antidotes against the poison with which his enemies at court attempted to destroy him. He early inured his body to hardship, and employed himself in the most manly exercises, often remaining whole months in the country, and making frozen snow and the earth the place of his repose. Naturally ambitious and cruel, he spared no pains to acquire power and dominion. He murdered the two sons whom his sister Laodice had by Ariarathes king of Cappadocia, and placed one of his own children, when only eight years old, on the vacant throne. This violent proceeding alarmed Nicomedes king of Bithynia, who had married Laodice the widow of Ariarathes, and ultimately involved Mithridates in a quarrel with the Romans. Mithridates never lost an opportunity by which he might lessen the influence of his adversaries; and in order the more effectually to destroy their power in Asia, he commanded that all the Romans who were in his dominions should be massacred. This was done in one night, and no less than a hundred and fifty thousand according to Plutarch, or eighty thousand according to Appian, became the victims of his cruelty. This atrocious butchery called aloud for vengeance. Aquilius, and soon afterwards Sylla, marched against Mithridates with a large army. The former was made prisoner; but Sylla obtained a victory over the generals of Mithridates; and another decisive engagement rendered the great Roman captain master of all Greece, Macedonia, Ionia, and Asia Minor. This adverse fortune was aggravated by the loss of about two hundred thousand men, who were killed in the different engagements; and Mithridates, weakened by repeated reverses both by sea and land, sued for peace from the conqueror, which he obtained on hard terms. But he soon took the field again with an army of a hundred and forty thousand infantry and sixteen thousand horse, consisting of his own forces and those of his son-in-law Tigranes king of Armenia. At the head of this army he made himself master of the Roman provinces in Asia; none dared to oppose his conquests; and the Romans, relying upon his fidelity, had withdrawn the greater part of their armies from the country. But

the news of his warlike preparations were no sooner heard than Lucullus the consul marched into Asia, and without delay-blocked up the camp of Mithridates, who was then besieging Cyzicus. The Asiatic monarch, however, escaped, and fled into the heart of his kingdom. Lucullus pursued him with the utmost celerity, and would have taken him prisoner after a battle, had not the avidity of his soldiers preferred the plundering of a mule loaded with gold to the taking of a monarch who had exercised such cruelties against their countrymen. The appointment of Glabrio to the command of the Roman forces, instead of Lucullus, proved favourable to Mithridates, who recovered the greater part of his dominions. But the sudden arrival of Pompey soon put an end to his successes. During the night a battle was fought near the Euphrates, and an universal overthrow ensued; but Mithridates, bold in his misfortunes, rushed through the ranks of the enemy at the head of eight hundred horsemen, five hundred of whom perished in the attempt to follow him. He fled to Tigranes his son-in-law, who however refused him an asylum, although he had previously supported him with the collected forces of his kingdom. Mithridates found a safe retreat amongst the Scythians; and though destitute of power, friends, and resources, he yet meditated the overthrow of the Roman empire, by penetrating by land into the very heart of Italy. But these wild projects were rejected by his followers, and he sued for peace. It was denied to his ambassadors; and the victorious Pompey declared, that, in order to obtain it, Mithridates must ask it in person. The proud monarch scorned to trust himself in the hands of his enemy, and resolved to conquer or to die. His subjects, however, refused to follow him; and, having revolted against his authority, made his son Pharnaces king. The latter showed himself ungrateful to his father; and, according to some writers, he even ordered his parent to be put to death. This unnatural treatment broke the heart of Mithridates, who obliged his wife to poison herself, and attempted to do the same himself. But his attempt was in vain. The frequent antidotes he had taken in the early part of his life had strengthened his constitution against the poison; and when this proved unavailing, he attempted to stab himself. The blow did not prove mortal; and a Gaul who happened to be present gave him, at his own request, the fatal stroke, about sixty-four years before the Christian era. Such were the misfortunes, the abilities, and the miserable end, of a man who supported himself so long against the whole power of Rome, and who, according to the declarations of the Roman authors, proved a more powerful and indefatigable adversary than Hannibal, Pyrrhus, Perseus, or Antiochus. It is said that Mithridates conquered twenty-four nations, whose different languages he knew and spoke with the same ease and fluency as his own. As a man of letters he also deserves attention. He was acquainted with the Greek, and even wrote in that language a treatise on botany. His skill in physic is well known; and even now there is a celebrated antidote which bears his name, and is called *mithridate*. The great work of Adelung has also been called by his name.

MITRA was a cap or covering for the head, worn by the Roman ladies, and sometimes by the men; but it was looked upon as a mark of effeminacy in the latter, especially when it was tied upon their heads.

MITRE, a sacerdotal ornament worn on the head by bishops and certain abbots upon solemn occasions, being a sort of high cap, pointed and cleft at top. The high priest amongst the Jews wore a mitre or bonnet upon his head; and the inferior priests of the same nation had likewise their mitres, but in what respect they differed from that of the high priest is uncertain. Some writers contend that the ancient bishops wore mitres; but this is by no means a settled point.

Mitra
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Mitre.

Mitre
Island
||
M'Neil.

MITRE ISLAND, a small uninhabited island in the South Pacific Ocean, with two remarkable promontories. Long. 169. 55. E. Lat. 11. 49. S.

MITTAU, a city of the province of Courland, in European Russia, and the capital of a circle of the same name. It is in a marshy situation, at the junction of the river Drive with the Aa. It was once fortified, but the walls have gone to decay. The ancient palace of the dukes of Courland has been repaired for an imperial residence, but never so occupied. It contains seven churches, and, including the suburbs, 740 houses, with 12,420 inhabitants. There is here a college, with nine professors, and a library of 16,000 volumes. It has little trade except at a great fair, which continues four weeks. Long. 23. 20. E. Lat. 56. 45. N.

MITTIMUS, as generally used, has two significations. First, it signifies a writ for removing or transferring of records from one court to another. Secondly, it signifies a precept or command in writing, under the hand and seal of a justice of the peace, directed to the gaoler or keeper of some prison, for the receiving and safe keeping of an offender charged with any crime, until he be delivered by due course of law.

MITWEIDA, a city of the kingdom of Saxony, in the circle of Leipsig, and bailiwick of Rochlitz. It stands on the river Ztchopau, and is one of the most considerable places in Germany for the manufacturing of cotton goods. It contains 508 houses, and 3860 inhabitants.

MITYLENE, or MYTELENE, in *Ancient Geography*, a celebrated, powerful, and affluent city, the capital of the island of Lesbos. It received its name from Mitylene, the daughter of Macareus, a king of the country. It is greatly commended by the ancients for the stateliness of its buildings and the fertility of its soil; but more especially for the great men it produced, particularly Pittacus, Alcæus, Sappho, Terpander, Theophanes, Hellanicus, and others. It was long a seat of learning; and, with Rhodes and Athens, it had the honour of educating many of the great men of Rome and Greece. In the Peloponnesian war, the Mitylenians suffered greatly for their revolt against Athens; and in the Mithridatic wars they had the boldness not only to resist the Romans, but to disdain the treaties which had been concluded between Mithridates and Sylla.

MIXTURE, a compound or assemblage of several different bodies in the same mass. Chemical mixture is attended with many phenomena which are never observed in simple mixtures; such as heat, effervescence, &c. To chemical mixture belong the union of acids and alkalies, the amalgamation of metals, the solution of gums, &c.; and upon it depend many of the principal operations of chemistry.

MIZEN, or MIZZEN, in nautical language, is a particular mast or sail. The mizen-mast stands in the sternmost part of the ship. In some great ships there are two of these, in which case that next the main-mast is called the *main-mizen*, and that next the poop the *bonaventure mizen*.

MIZRAIM, or MISRAIM, the dual name of Egypt, employed in Scripture to denote the upper and lower divisions of that country. It sometimes occurs in the singular, *Mazor* (2 Kings, xix. Isaiah, xix. Micah, vii.).

M'NEILL,¹ HECTOR, a distinguished Scottish poet, born on the 22d of October 1746, at Rosebank, on the Esk, and almost amongst the classic woods of Hawthornden. Here his father, descended from an old respectable family in the south of Argyleshire, had retired from military service to enjoy the undisturbed calm of domestic life. Pecuniary cir-

cumstances, however, ere long forced him, with his family, from this choice retreat, to occupy a farm on the banks of Loch Lomond, where part of the boyhood of Hector, the youngest and favourite child, was spent amongst those scarcely less beautiful or less classic scenes, on which the young eyes of Buchanan and Smollett had gazed with delight; and where their "rural pipe," as well as his own, was first tuned to freedom and love.

His early education, with the exception of a short time spent at a school in the neighbourhood, was solely conducted by his father at home, who, along with the common branches, carefully imbued his mind with piety and good morals, and, with parental fondness and pride, also encouraged his boyish passion for the muses. Preparatory, however, to going to Bristol to the house of a wealthy mercantile relative, who had promised to provide for young Hector, the latter was, at the age of twelve, sent to Glasgow for two years, to acquire those branches immediately applicable to a commercial life. On his arrival at Bristol, he was occupied for a short time in the counting-house of his relative, and in completing his commercial education previously to his departure for the West Indies. Having spent three years, with neither comfort nor success, in mercantile pursuits in Antigua, and other three with strict honour and integrity in a civil capacity, in the office of the provost-marshal of Granada, he returned to his native land with the acquisition of the French language, but with no more wealth than when he departed.

Both his mother and sister had died in his absence, and his father did not survive his return above a year and a half. The small inheritance to which he thus succeeded he sunk in an annuity; but this only enabled him indolently to waste six valuable years in a connection which, howsoever regarded in the islands he had left, is still properly dishonourable in this, and which must, no doubt, as much as "the idle propensity of rhyming," have impeded his future success in life. The loss of his annuity by bankruptcy, however, broke the spell which had bound him, and urged him to seek some resource for warding off the immediate approach of want.

In this emergency, through the interest of a friend in London, he was appointed to the office of assistant-secretary in the flag-ship of Admiral Geary. Having made two cruises, the one under Admiral Geary, and the other under Admiral Darby, he resigned a situation which necessity alone had made him at first accept. Soon afterwards, however, he was induced to undertake the same office in the flag-ship of Sir Richard Bickerton, appointed to the East Indian station. During this service he was present in the last naval engagement with the able French commander Suffrein; and though his inkstand before him was swept away by the first broadside, and a block fell over his head on the quarter-netting, he evinced more calm intrepidity than the lyric bard of Rome in the battle of Philippi, or the unrivalled orator of Greece on the field of Chæroneæ.

Before leaving the Indian shores, on the conclusion of peace with America, he visited Surat, the sculptured excavations of Elephanta, and "smiling Salsett's cave-wrought coast." An account of these singular remains of Indian superstition and antiquity, his first attempt at authorship, beguiled the tedium of his voyage home, and was afterwards published in the *Archæologia*. Neither enriched with the gold of India, nor secured in a competence by a permanent appointment, he returned to Scotland after an absence of five years, where, to his mortification, he found, as too frequently happens, that success or adversity is considered as the proof of good or bad conduct.

¹ In strict accordance with the poet's usual orthography of his name, this article ought to have been placed under *Mac*, but unavoidable circumstances rendered this impracticable.

M'Neill.

The reversion of his bankrupt annuity being still unsettled, and economy necessary, he retired for two years to a humble residence in the neighbourhood of Stirling, distinguished alike by the beauties of nature and the memorials of national glory and independence. In this retirement, enhanced by the contrast of vertical suns and tropical scenes, and so congenial to thought and the muses, he produced the beautiful descriptive poem of "The Links of Forth," which gained him the enlightened friendship of Mr Graham of Gartmore.

The exhausted state of his pecuniary resources, however, compelled him to revisit the West Indies. On his arrival in Jamaica he was appointed to an office in the customhouse at Kingston; but the debilitating effects of fever, and other circumstances connected with his duties, obliged him to repair to the upland vale of Guanaboo, whose lively hues of vegetation, and "coolness wafted in perfume" from the orange, the logwood, and the lime (*citrus medica*, var.) at once exhilarated the mind and invigorated the constitution. Here, by a providentially good fortune, he met with two old school-fellows, whom distance and time now more closely united in friendship, and who, with a liberality becoming their wealth, made him share in their success. At the request of the distinguished Dr Currie, he drew up an impartial statement "on the treatment of the negroes," which was published at Liverpool by his esteemed friend, to whose memory he has done justice, both in "The Scottish Muse," and in "The Rose o' Kirtle:"

"And ye wha mourn at Currie's urn,
Or weep by Mersey's river,
Learn, that the rose that virtue blows,
Though dead, will bloom for ever."

Upon his passage home he composed the second canto of the sweetly wild poem of "The Harp," founded on a tradition of the Hebrides, and communicated to him by Graham of Gartmore, with whom, on his return to Stirlingshire, he lived for nearly two years in the closest intimacy of friendship. From prudential motives, however, and perhaps not a little in the spirit of "not burning his harp for woman," he retired from this loved abode to Argyleshire, in order to break off a mutual attachment between him and a near relative of his patron. But this separation told on his sensitive and feeling frame, though the interesting scenery of Argyleshire, the society of friends, and the composition of admired songs to the favourite airs of the country, considerably alleviated his tender pain.

Welcomed, from the popularity of his songs, by the fashionable society of Glasgow, he was, by the liberality of a friend, about to engage there in business, when, on the breaking out of the revolution in France, the commerce and prosperity of that city experienced a reverse so severe as completely to prevent the execution of his intentions. Soon after he was afflicted with a nervous disorder, which, by improper treatment, continued about six years. During this malady he fixed his residence for a time in a cottage near the field of Bannockburn, "dear to the muse, but doubly dear to liberty." Here, unable either to read or write above a few minutes without distress, he, like the blind minstrels of other times, composed "Scotland's Skaith," by memory alone; the happiest effort of his genius, and which induced his countrymen to consider him as the gifted bard on whom the inspiring mantle of Burns had fallen. The sequel to this simple, pathetic tale, which ran through fourteen editions in a year, he composed in the same manner, and published under the title of "The Waes of War;" but this was not so well received, from its being then considered as satirically reflecting upon the Dutch campaign.

In the hope of recovery from his long-protracted complaints, although by many deemed irremediable, he again sailed for Jamaica. This voyage happily contributed alike to restore his health and to afford him a future competence.

By the death of one of the companions of his boyhood, the Grahams of Three-Mile-River, whose kindness and liberality he had formerly experienced when in Jamaica, he now received a legacy, and the surviving brother settled on him an annuity for life. Under his friendly roof, previously to his return, he wrote "The Scottish Muse," descriptive of the various vicissitudes of his own poetical life; and also a grateful epitaph to his deceased friend, as in duty he might "with a brother's woes record his own."

Upon his arrival in Scotland, almost like one risen from the grave, when the voice of envy is silenced by death, a species of posthumous fame hailed his return. With the well-deserved emoluments of his poetical labours, and another bequest of an intimate medical friend in Jamaica, in addition to his annuity, he spent the evening of his days in the capital of his native land, in the enjoyment of publicly-awarded honour, lettered ease, and comparative affluence. Here he published "The Pastoral or Lyric Muse of Scotland," illustrative of the music and song of the Scottish Arcadia—the green hills and dales of the Teviot, Tweed, and Yarrow: also two satirical poems, entitled "Town Fashions," and "Bygone Times and Late Come Changes." His last literary efforts were "The Scottish Adventurers," and an unpublished autobiography in three volumes, which has been the chief guide in this brief account. Such were the calm labours of the years spent in Edinburgh, till the 15th March 1818, when, at an age beyond the common limit of human existence, he closed his frequently adverse, but not inglorious career, leaving a name endeared to his countrymen, and embalmed in the song of his father-land.

Born a poet, with a musical ear, a melodious voice, and a feeling mind, Macneill's disposition ill accorded with the rough life of the British seamen, and still less with the cautious acquiring habits of the merchant. From his attachment to truth, he was free, undisguised, and even severe; quick in temper, yet serene and social; proudly honourable, yet warm and benevolent. True to nature and feeling, as a poet he excels in the simple and pathetic; and though his humour and satire be less successful, his manner is serious and his aim uniformly well directed.

In the year 1801 an edition of his poetical works issued from the London press, in two vols. 12mo. The second edition, Edinburgh, 1806, in two vols. 12mo, contains additional songs, The Rose o' Kirtle, and Verses on Dr Doig, to whom the beautiful octavo edition of Scotland's Skaith, Edinburgh, 1795, is dedicated. The third edition, Edinburgh, 1812, in two vols. 12mo, does not, as might be supposed, contain the following poems, though written after the publication of the preceding edition: The Pastoral or Lyric Muse of Scotland, Edinburgh, 1808, 4to; Town Fashions, or Modern Manners delineated, Edinburgh, 1810, 12mo; Bygone Times and Late Come Changes, Edinburgh, 1811, 12mo.

His publications in prose are, an Account of the Caves of Canara, Ambola, and Elephanta, in the eighth volume of the Archæologia, 1787; On the Treatment of the Negroes in Jamaica, Liverpool, 1788; and The Scottish Adventurers, or the Way to Rise, a historical tale, two vols. Edinburgh, 1812, 8vo. (s. s.)

MNEMONICS. Some ancient writers speak of an artificial memory, and lay down rules for attaining it. Simonides the poet is said first to have made this discovery, or at least to have occasioned its being made. The story told of him is this. Being once at a feast, he recited a poem which he had composed in honour of the person who gave the entertainment; but having made a large digression in praise of Castor and Pollux, his patron, when he had repeated the whole poem, only gave him half the sum he had promised, telling him that he must get the rest from those deities who had an equal share in the ho-

nour of his performance. Immediately afterwards, Simonides was informed that two young men were without, and must needs speak with him. He had scarcely quitted the house, when the room where the company was assembled fell down, killed all the persons in it, and so mutilated the bodies that, when the rubbish was removed, they could not be distinguished one from another; but Simonides, calling to mind the place which every one had occupied, was by that means enabled to distinguish them. Hence it came to be observed, that fixing a number of places in the mind, in a certain order, served as a help to the memory; for we find by experience, that upon returning to places once familiar to us, we not only remember them, but likewise many things which we both said and did in them. This effort of Simonides was afterwards improved into an art, and its nature is simply this: You are required to form in your mind the idea of some large place or building, which you may divide into a great number of distinct parts, ranged and disposed in a certain order. These you are frequently to revolve in your thoughts, until, beginning at any part, you are able to run them over one after another without hesitation. Then you are to impress upon your mind as many images of living creatures, or any other objects which are most likely to affect you, and to be soonest revived in your memory. These, like characters written in short-hand, or like hieroglyphics, will stand to denote an equal number of words, which cannot so easily be remembered. When therefore you have a number of things to commit to memory in a certain order, all that you have to do is, to place those images regularly in the several parts of your building; and thus, by going over several parts of the building, the images placed in them will be revived in the mind, by which means the things or words themselves will arise in the order in which you desire to remember them. The advantage of these images seems to be this, that, as they are more likely to affect the imagination than the words for which they stand, they will for that reason be more easily remembered. Thus, for instance, if the image of a *lion* be made to signify *strength*, and this word *strength* be one of those which I am to remember, and be placed in the porch, then, in going over the several parts of the building, when I come to the porch I shall sooner be reminded of that image than of the word *strength*. Of this artificial memory both Cicero and Quintilian have spoken; but we know not of any modern orator who has ever made use of it. It seems indeed to have been a laborious way of improving the memory, if it serves that end at all, and fitter for assisting us to remember any number of unconnected words than a continual discourse, unless in as far as the remembrance of one word may enable us to recollect others. It is, however, in allusion to it that we still call the parts of a discourse *places* or *topics*, and say, in the first place, in the second place, and so on.

In Germany this art was revived by M. Aretin; and a pupil of his, M. Kaestner, was permitted to teach the new doctrine at Leipzig, but on the express condition of not allowing his hearers to write down his lectures. The following account is given of this art in a letter from Paris written in the beginning of 1807: "During my residence," says the writer, "in this metropolis, I heard a great deal of a new method of *mnémonique*, or of a method to assist and fix our memory, invented by Gregor de Feinaigle. Notwithstanding the simplicity with which he announced his lectures in the papers, I could not determine myself to become a pupil of his, as I thought to find a quack or mountebank, and to be laughed at by my friends for having thrown away my cash in such a foolish man-

ner. Perhaps I should hesitate to this moment about the utility of this newly-invented method to assist our natural memory, had I not had the pleasure of dining at his excellency's, the Count de Metternich, the Austrian ambassador, who followed, with all his secretaries, the whole course of lectures; they all spoke very advantageously of it, likewise several other persons of the first rank I met there. In consequence of this I was inserted into the list of pupils, and I follow at this moment the lectures. All I can tell you about this method is, it is a very simple one, and easy to be learned, adapted to all ages and sexes. All difficulties in such sciences as require an extraordinary good memory, for instance, the names and epochs in history, are at once overcome and obviated. There is not one branch of science to which this method cannot be applied. It is easy to be perceived that such an invention cannot pass without some critique, and even sarcasms, in the public prints; some of them were very injurious, and plausible enough to mislead the public, who, knowing nothing of the method, are always more ready to condemn than to assist. M. Feinaigle, to answer all these critics at once, adopted a method not less public for Paris than the public papers, but less public for the rest of Europe. He gave a public exhibition to about 2000 spectators, in which he did not appear at all, only about twelve or fifteen of his pupils; each of them made such an application of the method as his situation in life required. The principal parts were the following: History, about names and years; geography, with respect to longitude, latitude, number of inhabitants, square miles, &c.; grammar in various languages, about different editions of the same work; pandects, their division, and title of each book, title, &c.; different systems of botany, poetry, arithmetic, &c. At last one desired the company to give him one thousand words, without any connection whatsoever, and without numerical order; for instance, the word *astronomer*, for No. 62; *wood*, for No. 188; *lovely*, for No. 370; *dynasty*, for No. 23; *David*, for No. 90, &c. till all the numbers were filled; and he repeated the whole, notwithstanding he heard these words without order, and but once, in the numerical order; or he told you what word was given against any one number, or what number any one word bore. It is still more striking, but certainly also more difficult, to retain as many numbers, however great they may be. For words and numbers I could venture myself, with the greatest safety, as far as one hundred of each; and I am sure, after having fixed them once, which is done in less than ten minutes, I could repeat them to you at any period, without ever thinking any more of them."¹ Feinaigle afterwards delivered lectures on the same subject to crowded audiences in London, Edinburgh, Glasgow, and other towns; but we do not find that any of his pupils received improvement from his instructions, and very few of them could give any account of his method.

MNEMOSYNE, in fabulous history, a daughter of Cœlus and Terra, who married Jupiter, by whom she had the nine Muses. The word *mnemosyne* signifies *memory*; and therefore the poets have rightly called Memory the mother of the Muses, because it is to that mental endowment that mankind are indebted for their progress in science.

MOA ISLE, in the Eastern Seas, is situated off the eastern extremity of Timor, and intersected by the 128th degree of east longitude. Lat. 8. 20. S.

MOAB, in *Ancient Geography*, a country of Arabia Petræa, so called from Moab the son of Lot, to whose posterity this country had been allotted by divine appointment (Deut. xi. 9). It was originally occupied by the Emim,

¹ Phil. Mag. 23, 93

Moat
||
Mocha.

a race of giants extirpated by the Moabites. Moab anciently lay to the south of Ammon, before Sihon the Amorite stripped both nations of a part of their territory, which was afterwards occupied by the Israelites (Numb. xxi.); and then Moab was bounded by the river Arnon to the north, the *Lacus Asphaltites* to the west, the brook Zared to the south, and the mountains Abarim to the east.

MOAT, DITCH, or FOSSE, in *Fortification*, a deep trench dug round the rampart of a fortified place, to prevent surprises. See FORTIFICATION.

MOATAZALITES, or SEPARATISTS, a religious sect amongst the Turks, who deny all forms and qualities in the Divine Being, and divest God of his attributes.

Amongst the Turkish divines two opinions are entertained concerning God. The first admits metaphysical forms or attributes, as, that God has wisdom, by which he is wise; power, by which he is powerful; eternity, by which he is eternal; and so of the rest. The second allows God to be wise, powerful, eternal; but does not admit any form or quality in God, for fear of admitting a multiplicity. Those who hold the latter opinion are called *Moatazalites*; they who adopt the former, are denominated *Sephalites*. This sect is said to have first invented the scholastic divinity: it is subdivided into no less than twenty inferior sects, which mutually brand one another with infidelity.

MOBILE, a city, port of entry, and capital of Mobile county, in Alabama, one of the United States of North America. It is situated on the west side of Mobile River, at its entrance into the bay, thirty miles north of Mobile Point, which is upon the east side of the mouth of the bay, fifty-miles west by north from Pensacola, and 160 miles east from New Orleans. Although its site is dry and pleasant, in rear of it there are swampy lands and stagnant waters, and near it is a sterile country of pine woods. It possesses a considerable trade in cotton, and in this respect ranks next to New Orleans and Charleston. The value of the exports of domestic produce from Alabama in 1829 amounted to 1,679,385 dollars, and nearly the whole of this must have been shipped at Mobile. The exports have since considerably increased. This city has a regular steam-boat communication with New Orleans through Lake Ponchartrain. During most of the year steam-boats are constantly plying between this place and the towns on the river, and many vessels are continually loading at the wharfs for distant ports. In January 1836, the Mobile and Tennessee Railway Company was incorporated. This work is to extend from the city or bay of Mobile to some point on the Tennessee River, and thence north to the Tennessee line. Mobile has a bank, and issues two daily papers. The population is estimated at between 4000 and 5000. Long. 88. 21. W. Lat. 30. 40. N.

MOBILE, *Moveable*, any thing susceptible of motion, or that is capable of being moved either by itself or by some other prior mover.

Primum MOBILE, in the ancient astronomy, was a ninth heaven or sphere, imagined to exist above those of the planets and fixed stars. This was supposed to be the first mover, and to carry round all the lower spheres along with it; communicating to them a motion by which they revolved in twenty-four hours. But the diurnal revolution of the planets is now accounted for without the assistance of any such *primum mobile*.

Perpetuum MOBILE. See PERPETUAL MOTION.

MOCHA, one of the principal ports of the Red Sea, and the chief city of the province of Yemen, in Arabia. It has a handsome appearance from the sea, all its buildings being white-washed, and several of its minarets overtopping the other buildings, whilst some of the tombs, which, as in many eastern cities, are handsome structures, break the monotonous view of the flat roofs which are common in Mahomedan cities. But if the eye is pleased by the

Mocha

external aspect of the place, these ideas are quickly dispelled by a nearer view, owing to the filth which covers the streets and all the open places, and the mean and ruined state of many of the houses, which, being generally built of unburnt bricks, with little lime, are destroyed by the introduction of moisture, which decomposes the fragile materials of which these buildings are composed, and the bricks in consequence return to their original state of mud. The principal edifice is the residence of the Dola, which is large and lofty, having one front to the sea, and another to a square, which forms the only regular portion of the town. The other sides of this square are occupied by the residences of the other public functionaries, and by one extensive serai built by the Turks whilst they were in possession of the place. Those houses which front the sea, with their turreted tops and fantastic ornaments of white stucco, make a respectable appearance. They have mostly small and irregularly-placed windows, and in the upper apartments they substitute for glass a thin strata of a transparent stone found in a mountain near to Sana. These windows are mostly of a circular form. The houses are but rudely finished in the interior, the floors and roofs being made of chunam, and very uneven; the passages in them are long and narrow, and their staircases very steep. Those of the lower classes are still more rude, being mere huts of brick covered in the inside with mats, and sometimes in the outside with a little clay, with which the roof is thatched. The town is fortified by a wall sixteen feet towards the sea, but thirty feet towards the land; and it extends for about a mile in nearly a straight line facing the sea, and afterwards takes a circular direction. It is of no strength, and would be shattered to pieces by the first shock of artillery; in some places, indeed, it would scarcely bear the firing of its own cannon. Nor are the forts which defend it in any better condition. They might all be levelled to the ground by a single broadside from an English man-of-war. Its only use was to repel an irregular attack of the Wahabee cavalry. The garrison consists of about 200 musqueteers and eighty cavalry, who receive two dollars of pay per month, and provide their own arms and ammunition. Mocha possesses a considerable trade, and is the channel through which the intercourse of Europe with this part of the world is carried on. Coffee is the main staple, and is indigenous to the country, which produces it in great abundance, and of unrivalled excellence. It was introduced from Arabia into Aleppo and Damascus, and other great cities. It became known in France and England in the middle of the seventeenth century; the demand for it increased, and it became a source of wealth; but the shrub having been transplanted to the West Indies, the cheaper coffee of these countries, though of inferior quality, rivalled the produce of Mocha in the European markets. The whole quantity of coffee produced at Mocha, amounting, according to the estimate of Lord Valentia, to 4,880,000 lbs. was formerly conveyed to Jidda, where it was purchased by merchants from Europe or from India, and partly also from America. Mocha also carries on a considerable trade in myrrh, frankincense, and gum-arabic, which commodities are brought from the opposite coast of Berbera, in Africa; in balm of Gilead or of Mekka, a resinous juice much used in the East as a cosmetic; in senna, of which about 30,000 cwt. are exported; in sharks' fins, rhinoceros' horns and hides, acacia and civet from the interior of Africa. Grain and piece-goods are imported to a considerable amount from Bombay. The trade is carried on by about 250 Banians or Gentoo merchants, who are subject to great oppression, and who are only induced to remain from the great profits which they realize. Three per cent. of custom duty is imposed on English goods, and on those of other foreigners five per cent. A three-masted vessel pays 384 dollars on its arrival, and vessels with two masts only

Mocha
Model.

one half each. Mocha is not a city of any antiquity. It does not appear to have been known so far back as four centuries. When it was visited by Alphonso Albuquerque in 1513, it seems to have been an inconsiderable place. The first attempt to open a trade with it was in 1610, by the British expeditions under Sharpey and Sir H. Middleton. It was here that the latter was treacherously surprised and made prisoner with a number of his men, though he afterwards obtained his release, and exacted satisfaction for the injuries which he had received. The Dutch took the lead amongst the Europeans in establishing a factory here; and they were followed in 1708 by the French, and afterwards by the English, who at length engrossed almost the whole trade, till they found formidable rivals in the Americans. The surrounding country is a dreary plain of arid sand, environed by mountains, and covered with a saline efflorescence, scarcely relieved in some parts by embrowned leaves and stunted vegetables, whose burnt appearance does not diminish the dreariness of the scenery. Dates grow in abundance around the town, but, like every thing else, are affected by the poverty of the soil from which they spring. The south-east wind, which blows for eight months of the year, and passes over the burning sands of Africa, renders the climate intensely hot. The north-west wind, which blows for the other four months, is also hot, as it passes over the burning sands of Arabia. It is supposed by travellers that the town does not contain above 5000 inhabitants. Long. 43. 20. E. Lat. 13. 20. N.

MOCHA, an island off the coast of Chile, above sixty miles in circumference. It is fertile, and was formerly settled by Spaniards, but it is now uninhabited. It is, however, frequented by whale ships belonging to England and the United States.

MOCKWANPORE, a district of Hindustan, situated principally between the twenty-seventh and twenty-eighth degrees of north latitude, and bounded on the south by Bettiah and Tirhoot in Bahar. It is a fertile valley, and produces abundance of rice. The capital is of the same name; it is situated on a hill, surrounded by a stone wall, and forms a hill-fort of considerable strength. Long. 85. 18. E. Lat. 27. 28. N.

MODAIN, UL, a village of Irak Arabi, which occupies the site of Seleucia and Ctesiphon, on the eastern bank of the Euphrates. Little else remains excepting ruins of those once magnificent cities. It is twenty miles south-east of Bagdad.

MODANIA, a town of Asia Minor, situated on a gulf of the same name, on the Sea of Marmora. It was anciently called Myrlea and Apamea, the ruins of which are still visible. It is fifteen miles north-west of Bursa.

MODBURY, a town in the county of Devon and hundred of Ermington, 210 miles from London. It has some few cloth manufactories, and a good market on Thursday. It is celebrated for its white ale. The population amounted in 1801 to 1813, in 1811 to 1890, in 1821 to 2194, and in 1831 to 2116.

MODE, a word of the same general import with MAN-
NER, is used as a technical term in grammar, metaphysics, and music. See the articles on these subjects.

MODEL, in a general sense, signifies an original pattern, proposed for any one to copy or imitate.

This word is particularly used, in building, to signify an artificial pattern made in wood, stone, plaster, or other matter, with all its parts and proportions, being intended for the better conducting and executing some great work, and to give an idea of the effect it will have in its proper dimensions. In all great buildings, it is much the surest way to make a model in relief, and not to trust to a bare design or draught. There are also models for the building of ships, and for many other purposes.

Models are likewise used in painting and sculpture; and

hence, in academies, they give the term *model* to a naked man or woman, disposed in several postures, to afford an opportunity to the scholars to design them in various views and attitudes.

Model.

Models in imitation of any natural or artificial substance are most usually made by means of moulds composed of plaster of Paris. For the purpose of making these moulds, this kind of plaster is much fitter than any other substance, on account of the power it has of absorbing water, and soon condensing into a hard substance, even after it has been rendered so thin as to be of the consistence of cream. This happens in a shorter or longer time, according as the plaster is of a better or worse quality; and its good or bad properties depend very much upon its age, to which, therefore, particular regard ought to be had. It is sold in the shops at very different prices, the finest being made use of for casts, and the middling sort for moulds. It may be very easily coloured by means of almost any kind of powder excepting what contains an alkaline salt; for this would chemically decompose the substance of the plaster, and render it unfit for use. A considerable quantity of chalk would also render it soft and useless, but lime hardens it to a great degree. The addition of common size will likewise render it much harder than if mere water is made use of. In making either moulds or models, however, we must be careful not to make the mixture too thick at first; for if this be done, and more water be added to thin it, the composition must always prove brittle and of a bad quality.

The particular manner of making models, or *casts*, as they are also called, depends on the form of the subject to be taken. The process is easy where the parts are elevated only in a slight degree, or where they form only a right or obtuse angle with the principal surface from which they project; but where the parts project in smaller angles, or form curves inclined towards the principal surface, the work becomes more difficult. This observation, however, holds good only with regard to hard and inflexible bodies; for such as are soft may often be freed from the mould, even although they have the shape last mentioned. But although this be the case with the soft original substance, it is not so with the inflexible model when once it is cast.

The moulds are to be made of various degrees of thickness, according to the size of the model to be cast; they may be from half an inch to an inch, or, if very large, an inch and a half. Where a number of models are to be taken from one mould, it will likewise be necessary to have it of a stronger contexture than where only a few are required; and this for very obvious reasons.

It is much more easy to make a mould for a soft substance than a rigid one, as in any of the viscera of the animal body; for the fluidity of the mixture makes it easily accommodate itself to the projecting parts of the substance; and as it is necessary to inflate these substances, they may be very readily extracted again by letting out the air which distended them.

When a model is to be taken, the surface of the original is first to be greased, in order to prevent the plaster from sticking to it; but if the substance itself be slippery, as is the case with the internal parts of the human body, this need not be done. When necessary, it may be laid over with linseed oil, by means of a painter's brush. The original is then to be placed on a smooth table, previously greased or covered with a cloth, to prevent the plaster from sticking to it; then the original is surrounded with a frame or ridge of glaziers' putty, at such a distance from it as will admit the plaster to rest upon the table on all sides of the subject, for about an inch, or as much as is sufficient to give the proper degree of strength to the mould. A sufficient quantity of plaster is then to be poured as uniform-

Model. ly as possible over the whole substance, until it be everywhere covered to such a thickness as to give a proper substance to the mould, which varies in proportion to the size. The whole must then be suffered to remain in this condition until the plaster has attained its hardness. When the frame is taken away, the mould may be inverted, and the subject removed from it; and when the plaster is thoroughly dry, let it be well seasoned.

The moulds being thus formed and seasoned, they must next be prepared for the casts by greasing the inside of them with a mixture of olive oil and lard in equal parts, and then filled with fine fluid plaster, and the plane of the mould formed by its resting on the surface of the table covered to a sufficient thickness with coarse plaster, to form a strong basis or support for the cast where this support is requisite, as is particularly the case where the thin and membranous parts of the body are to be represented. After the plaster is poured into the mould, it must be suffered to stand until it has acquired the greatest degree of hardness it will receive; after which the mould must be removed: but this will be attended with some difficulty when the shape of the subject is unfavourable; and in some cases the mould must be separated by means of a small mallet and chisel. If by these instruments any parts of the model should be broken off, they may be cemented by making the two surfaces to be applied to each other quite wet, then interposing betwixt them a little liquid plaster, and smoothing the joint after being thoroughly dry. Any small holes which may be made in the mould can be filled up with liquid plaster, after the sides have been thoroughly wetted, and smoothed over with the edge of a knife.

In many cases it is altogether impracticable to prepare a mould of one piece for a whole subject; and therefore it must be considered how this can be effected in such a manner as to divide the mould into the fewest pieces. This may be done by making every piece cover as much of the pattern as possible, without surrounding such projecting parts, or running into such hollows, as would not admit a separation of the mould. It is impossible, however, to give any particular directions in this matter which can hold good in every instance, the number of pieces of which the mould is to consist being always determined from the shape of the pattern. Thus the mould of the human calculus will require no more than three pieces, but that of an *os femoris* could scarcely have fewer than ten or twelve. Where any internal pieces are required, they are to be first made, and then the outer pieces after the former have become hard.

To make a mould upon a hard and dry substance, we must, in the first place, rub the surface of it smoothly over with the mixture of oil and lard above mentioned. Such hollows as require internal pieces are then to be filled up with fluid plaster; and whilst it continues in this state, a wire loop must be introduced into it, by which, when hardened, it can be pulled off. The plaster should be somewhat raised in a pyramidal form around this wire, and afterwards cut smooth with a knife whilst yet in its soft state; preserving two or three angular ridges from the loop to the outer edge, that it may fix the more steadily in the outer piece of the mould to be afterwards made upon it. Let the outer piece then be well greased, to prevent the second piece from adhering; the loop being enclosed with some glaziers' putty, both to prevent the second piece from adhering, and to preserve a hollow place for the cord.

To form the second or outside piece, mix a quantity of plaster, proportioned to the extent of surface it is to cover and the intended thickness of the mould. When it is just beginning to thicken, or assumes such a consistence as not to run off very easily, spread it over the internal piece or pieces as well as the pattern, taking care at the same

time not to go too far, lest it should not deliver safely; and as the plaster becomes more tenacious, add more upon the pattern, until it has become sufficiently thick, keeping the edges square and smooth like the edge of a board. The plaster should be spread equally upon all parts, which is best done by a painter's pallet knife or apothecary's bolus knife; but for this the instrument should be somewhat less pliable than it is commonly made.

When the outside piece becomes hard, the edges are to be pared smooth, and made nearly square with a small pointed knife. Little holes of a conical shape are to be made with the point of a knife, about an inch distant from one another, according to the size of the piece. These are designed to receive the fluid plaster in forming the adjacent parts of the mould, and occasion points corresponding to the hollows; and they are intended to preserve the edges of the different pieces steadily in their proper relative situations. The third piece is then to be formed in a manner similar to the second, greasing the edges of the former plentifully with hog's lard and oil, to prevent the pieces from adhering to each other. Thus the pattern is to be wholly enclosed, only leaving a proper orifice for pouring in the plaster to form the model; small holes being also bored in the mould opposite to the wire-loops fixed in the inside pieces, through which a cord is to be conveyed from the loop to confine such pieces during the time of casting. In some cases, however, it is not necessary that the mould should totally enclose the pattern; for instance, where a model is to be made of a pedestal, or a bust of any part of the human body. The bottom of such moulds being left open, there is accordingly ample room left for pouring in the plaster.

After the mould is completely formed, it is next to be dried either naturally or by a gentle artificial heat, and then seasoned in the following manner. Having been made thoroughly dry, which, if the mould is large, will require two or three weeks, it is to be brushed over plentifully with linseed oil boiled with sugar of lead, finely levigated litharge, or oil of vitriol. The inside and joints of the mould should be particularly well supplied with it. If the mould be large, it is needless to attend to the outside; but when the moulds are small, it will not be improper to boil them in the oil, by which means their pores are more exactly filled than could otherwise be done. After the moulds have undergone this operation, they are again set by to dry, when, being greased with olive oil and hog's lard, they are fit for use. If linseed oil be used for greasing the moulds, it will in a short time impart a disagreeable yellow colour to the casts.

The mould being properly prepared and seasoned, nothing more is requisite to form the model than to pour into it the finest liquid plaster of Paris. After a layer of this, about half an inch in thickness, has been formed all round the mould, the coarser kind may be used to fill it up entirely, or to give to the model the thickness required.

Besides the models which are taken from inanimate bodies, it has been frequently attempted to take the exact resemblance of people whilst living, by using their face as the original of a model from which to take a mould; and the operation, however disagreeable, has been submitted to by persons of the highest ranks in life. A considerable difficulty occurs in this, however, by reason of the person being apt to shrink and distort his features when the liquid is poured upon him; neither is he altogether without danger of suffocation, unless the operator understand his business thoroughly.

To avoid the former inconvenience, it will be proper to mix the plaster with warm instead of cold water, by which means the person will be under no temptation to shrink; and to prevent any danger of a fatal accident, the following method is to be practised: Having laid the person

Model.

Modena. horizontally on his back, the head must first be raised by means of a pillow to the exact position in which it is naturally carried when the body is erect; then the parts to be represented must be very thinly covered over with fine oil of almonds by means of a painter's brush; the face is then to be first covered with fine fluid plaster, beginning at the upper part of the forehead, and spreading it over the eyes, which are to be kept close, that the plaster may not come in contact with the globe; yet not closed so strongly as to cause any unnatural wrinkles. Then cover the nose and ears, plugging first up the *meatus auditorius* with cotton, and the nostrils with a small quantity of tow rolled up, of a proper size, to exclude the plaster. During the time that the nose is thus stopped, the person is to breathe through the mouth. In this state the fluid plaster is to be brought down low enough to cover the upper lip, observing to leave the rolls of tow projecting out of the plaster. When the operation has been thus far carried on, the plaster must be suffered to harden; after which the tow may be withdrawn, and the nostrils left open and free for breathing. The mouth is next to be closed in its natural position, and the plaster brought down to the extremity of the chin. Begin then to cover that part of the breast which is to be represented, and spread the plaster to the outsides of the arms and upwards, in such a manner as to meet and join that which has been previously laid on the face. When the whole of the mass has acquired its due hardness, it is to be cautiously lifted, without breaking or giving pain to the person. After the mould is constructed, it must be seasoned in the manner already directed; and when the cast is taken, it must be separated from the mould by means of a small mallet and chisel. The eyes, which are necessarily shown closed, are to be carved, so that the eyelids may be represented in an elevated posture; the nostrils must be hollowed out, and the back part of the head, from which, on account of the hair, no mould can be taken, must be finished according to the skill of the artist. The edges of the model are then to be neatly smoothed off, and the bust fixed upon its pedestal.

The method of making models in plaster of Paris is undoubtedly the most easy way of obtaining them. When models, however, are made of such large objects that the model itself must be of considerable size, it is vain to attempt making it in the way above described. Such models must be constructed by the hand with some soft substance, as wax, clay, putty, and the like; and it being necessary to keep all the proportions mathematically exact, the construction of a single model of this kind must be a work of great labour and expense, as well as of time.

MODENA, an independent sovereign state in the north of Italy, the chief of which bears the title of his Royal Highness the Duke of Modena, Reggio, Mirandola, Massa, and Carrara, and is descended from a branch of the Austrian family. This sovereign is descended from the house of Este, one of the most ancient families in Europe. A member of that house, then settled in Lombardy, became Marquis of Modena in 960; and his successor, in 1097, obtained the sole power over Milan and Genoa, under the name of Azzo II. He was the founder of that family, one branch of which having settled in Bavaria, and afterwards becoming possessed of Brunswick, in Germany, gave origin to that race of monarchs of which five in succession have filled the throne of Great Britain. During the civil wars which raged in Italy in the course of the thirteenth century, when so many small republics were formed, the territories of Ferrara, Modena, and Reggio, chose the then Marquis of Este, Obizzo III. who had attained great respect as a warrior, for their supreme lord. One of his successors, Borso d'Este, was, in 1452, raised to the dignity of Duke of Modena and Reggio by the Emperor Frederick III. Alfonso II. having no legitimate male issue, obtained from the Em-

peror Rudolph II. permission to nominate as successor a son of his uncle by a doubtful or left-handed marriage, who had gained the sovereignty under the name of Cæsar d'Este, and from whom are descended the present reigning race. These have since gained from the popes some additional territory, and also a portion from the emperors originally granted as feudal tenures, but successively affirmed as permanent sovereignty. The last acquisition was Carrara, gained by the marriage of the duke with the heiress of the duchies of Massa and Carrara in 1741. The issue of this marriage was only a daughter, who married the Archduke Ferdinand of Austria, the brother of Joseph II. and of Leopold II. whose son succeeded to the dominions.

In 1796, the French expelled the duke, and his territory was formed into a province of the ephemeral Cisalpine republic; and, by the peace of Campo Formio, the duke was to receive an indemnification in Suabia. It then became a part of Bonaparte's kingdom of Italy; but after his fall, it was, by the congress of Vienna in 1814, restored to the ancient family which had before possessed it.

This state extends in north latitude from 43. 56. 10. to 44. 57. 30. and in east longitude from 10. 20. 25. to 11. 17. 2. It is bounded on the north by the Austrian kingdom of Lombardy and by Guastalla, on the east by the papal dominions, on the south-east by Tuscany, on the south by Lucca, on the south-west by Tuscany, and on the west by Parma. It extends over 2140 square miles, and contains at present 395,000 inhabitants, being one of the most densely-peopled districts in Europe. The Apennine Mountains form a part of the southern division of the territory, and the rest is generally a level plain, very gradually declining towards the north, and watered by several small streams which finally unite in the river Secchia, and empty themselves into the Po. There are numerous canals, formed chiefly for the purpose of irrigation. The soil is generally fertile. The system of cultivation so nearly resembles that already fully described in this work under the head of LOMBARDY, that the reader is referred to that article. We have only to remark here, that the olive trees are much more numerous than in Lombardy, and that the oil expressed from their fruit is much esteemed, and forms an article of the export trade.

The chief product is silk, some of which is organized before being exported, but most of it is sent to foreign markets in the raw state: a small portion only of it is manufactured into finished goods within the territory. The other fabrics are of hemp and flax, and only for domestic consumption. The country is divided into six ecclesiastical dioceses, each with a bishop, and in the capital an archbishop; and the whole of the inhabitants adhere to the Roman Catholic church, with the exception of about 1200 Jews, who reside chiefly in and around the capital. It contains ten cities, sixty-three market-towns, forty-nine communes, and 463 villages. The larger cities and their population are, Modena with 27,000 inhabitants, Reggio with 18,000, Massa with 7000, and Carrara with 4000; the others, though they were once walled, are now inconsiderable. The annual revenue of the whole state amounts to about L.150,000, the chief part being derived from patrimonial estates; and besides that, the duke enjoys the valuable property of the ancient house of Obizzi, near to Treviso in Austrian Lombardy, which is said to produce him annually L.20,000. The expenditure of the state is nearly equal to the annual income; and the whole debt does not quite amount to the revenue of half a year. The duke maintains an armed force, which, including 100 cavalry and his guards, amounts to about 1800 men.

The capital city, of the same name, is in north latitude 44. 34. and in east longitude 11. 7. 25. It is situated on the banks of a canal, by which it is connected with the rivers Secchia and Panaro, and is surrounded with walls

Moderator and defended by bastions; but it is not deemed capable of much defence, more especially as the citadel is very weak. **Modica.** It is a well-built city, with a broad street, the Corso, running from one gate to the opposite one. The houses are handsome, and mostly furnished with piazzas on the ground floor. The most distinguished building is the ducal palace. It is surrounded with a garden, which is used as a place of recreation for the inhabitants. It is built of marble, contains a library of 80,000 volumes, and many antiquities; but the collection of paintings, which was formerly the chief attraction, has been transferred by sale to Dresden. The cathedral, the theatre, the opera-house, and the barracks, are the other most remarkable edifices in the city. There are within the city no less than fifty churches, of which twenty-six formerly belonged to religious houses. Of late the duke has restored the Jesuits, and the order is more flourishing here than in any of the other cities of Italy. There is a university with seven professors, a gymnasium, a scientific society, an academy for nobles, and a veterinary college. But there is little trade of any kind, and the inhabitants chiefly depend on the expenditure of the court for their subsistence.

MODERATOR, in the schools, the person who presides at a dispute, or in a public assembly. Thus the president of the annual assembly of the church of Scotland is styled *moderator*.

MODERN, or *Modor*, a city of the circle of Presburg, in the Austrian kingdom of Hungary. It stands at the foot of the Carpathian Mountains, and has a Catholic and a Lutheran church, and a lyceum for the latter sect. It contains 592 houses, and 4573 inhabitants, who make some good woollen cloths. It is situated in longitude 17. 11. 57. E. and latitude 48. 20. 14. N.

MODESTY, in *Ethics*, is sometimes used to denote humility, and sometimes to express chastity or purity of sentiments and manners. The idea of modesty is not a chimera, a popular prejudice, or an illusion arising from laws and education. Nature, which speaks the same language to all men, has, with the unanimous consent of nations, annexed contempt to female incontinence. To resist and to attack are laws of her appointment; and whilst she bestows desires on both parties, they are in the one accompanied with boldness, in the other with shame. To individuals she has allotted long spaces of time for the purposes of self-preservation, and but moments for the propagation of their species. What arm more gentle than modesty could she have put into the hands of that sex which she designed to make resistance?

If it were the custom for both sexes to make and receive advances indiscriminately, vain importunity would not be prevented. The fire of passion would never be stirred up, but languish in tedious liberty; the most amiable of all feelings would scarcely warm the human breast, and its object would with difficulty be attained. That obstacle which seems to remove this object to a distance, in fact brings it nearer. The veil of shame only makes the desires more attractive. Modesty kindles that flame which it endeavours to suppress; its fears, its evasions, its caution, its timid avowals, its pleasing and affecting finesses, speak more plainly what it wishes to conceal than passion could ever do without it.

MODICA, a city of the island of Sicily, in the kingdom of Naples, in the province of Noto, 120 miles from Palermo. It is the capital of a district of the same name, which extends over 120,000 square miles, and contains 80,000 inhabitants, who are said to be the most active and wealthy of any of the inhabitants of Sicily, and produce the most abundant supplies of corn, tobacco, oil, wine, soda, hemp, wool, canary seed, cheese, and butter, which is chiefly exported to Malta. The city is built amongst straggling craggy rocks, but contains several beautiful edifices, espe-

cially a fine Franciscan convent and two hospitals. **Al-Modillions** though situated in a humid atmosphere, it contains 21,000 inhabitants. **Mogadore.**

MODILLIONS, in *Architecture*, ornaments in the cornice of the Ionic, Corinthian, and Composite columns.

MODIUS, a Roman dry measure for all sorts of grain, containing thirty-two heminae, or sixteen sextarii, or one third of the amphora, amounting to an English peck. See **MEASURE**.

MODULATION, the art of forming any thing to a certain proportion.

MODULATION, in *Music*, derived from the Latin *modulari*. This word, in our language, is susceptible of several different significations. It frequently means no more than an air, or a number of musical sounds properly connected and arranged. Thus it answers to what is sometimes understood by the word *tune*, and likewise expresses the French word *chant*. But the precise and technical acceptation to which it ought to be confined, is the art of composing melody or harmony agreeably to the laws prescribed by any particular key, rather than of changing the key, or of regularly and legitimately passing from one key to another.

MODULE, in *Architecture*, a certain measure, or dimension, taken at pleasure, for regulating the proportions of columns, and the symmetry or disposition of the whole building. Architects generally choose the semidiameter of the bottom of the column for their module, and this they subdivide into parts or minutes.

MOEN, or **MOENHØE**, an island in the Baltic Sea, part of the kingdom of Denmark. It is separated by a narrow strait on the north from Zealand, and by one still narrower on the west from Falster. It extends over ninety-five square miles, or about 61,000 acres, and contains one town and three villages, with 2500 inhabitants. The soil is generally good, producing excellent corn, especially barley and fruit, culinary vegetables, and flax in abundance. The annual surplus of corn is commonly 10,000 quarters. Agriculture and the fisheries are the chief employments of the inhabitants. The capital, Stege, is situated on a small bay, in longitude 11. 3. 4. E. and latitude 55. N., and contains a population of about 1000 persons.

MOFFAT, a small well-built town, and a celebrated watering-place, of Scotland, in the county of Dumfries. It is situated on a beautiful eminence near the junction of the Annan and Moffat waters, and is on all sides except the south encompassed by hills of various elevation. In the neighbourhood, especially to the north and west of the town, are sheltering plantations, which impart considerable beauty to the environs, as well as an air of comfort to the place itself. It consists principally of one main street, looking from the gentle declivity on which Moffat stands towards the south; and a fine prospect of the vale beneath is thus afforded. This street is judiciously laid out, spacious, and well calculated to form an agreeable promenade for both inhabitants and strangers. The church, which is a substantial stone edifice, was built towards the close of the last century. Besides this place of worship, the town is provided with a meeting-house for the United Associate Synod. Much of the town is new; and amongst the buildings are two good inns, various minor houses of entertainment, and many private ones in which comfortable lodgings may be obtained. The medicinal springs, which give celebrity to the place, and render it a favourite resort for invalids, are three in number; one of them is sulphureous, and the other two are chalybeate. The first is useful in cutaneous diseases, and the other two in affections of the stomach, and other complaints. The population of the town and parish was, in 1821, 2218, and in 1831, 2221.

MOGADORE, or **MOGODORE**, but by the natives called Suera or Saweera, is a considerable sea-port of Morocco,

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Moguls

in the province of Shedma. This town, which was built by Sidi Mohammed in 1760, stands upon a sandy beach forming a peninsula, the foundation of which is rocky, and is separated from the cultivated country by a range of shifting sand-hills. A chain of rocks, extending from the northern to the southern gate, defends the town from the encroachments of the sea; but at spring-tides it is nearly insulated. It consists of two parts, a citadel and an outer town. The customhouse, treasury, residence of the alcaid, and the houses of the European merchants, are situated in the former. The factory of Mogadore consists of ten or twelve mercantile houses of different nations, whose owners, from the protection granted to them by the emperor, live in complete security from the Moors, and keep them at a rigid distance. With the exception of those who belong to the body of foreign merchants, the Jews are compelled to reside in the outer town, which, however, is walled in and protected by batteries, as well as the citadel. Mogadore was built according to plans furnished by a French engineer; and, as far as parapets, ramparts, embrasures, cavaliers, batteries, and casemates, constitute a fortress, this is one; but these are of so flimsy and imperfect construction as to be incapable of protecting the place for any length of time against a regular force. The streets are laid out in right lines, but they are unpaved and very narrow. The houses, although lofty and regular, have a sombre aspect, from there being few windows facing the street. There is a handsome market-place surrounded with piazzas, and the public buildings have a neat appearance; but the situation is ill chosen, the immediate neighbourhood being an absolute desert. The port is formed by a curve in the land, and by an island nearly two miles in circumference, situated about a quarter of a mile from the shore; but as there is only ten or twelve feet of water at ebb-tide, large vessels lie at anchor a mile and a half west of the battery, which extends along the west side of the town. The mouth of the harbour is narrow, yet a heavy sea rolls in; but behind the island the anchorage is good. The battery, like the other defensive works of Mogadore, is much more remarkable for its beauty than its strength. The roadstead is very much exposed at certain seasons; and this port, although the only one in the empire which maintains a regular and uninterrupted commercial intercourse with Europe, is in many respects inferior to that of El Waladia. Besides, the town is invested with shifting sand-hills, which, blown about by the winds of winter, prove a great annoyance. In the neighbourhood are cultivated parts, where barley and millet are chiefly raised; and there are also fruits and esculent vegetables produced, principally pomegranates, melons, figs, pomatas, and pease as good as those of England. Notwithstanding many disadvantages, the climate of Mogadore is salubrious, and not inimical to Europeans. Considerable quantities of that leather which bears the name of the empire is prepared at this place. The population, according to Jackson, is 10,000; but other authorities estimate it as high as 30,000, which is certainly an exaggeration. Long. 9. 35. 30. W. Lat. 31. 32. 40. N.

MOGNANO, a town of the kingdom of Naples, in the province Terra di Lavoro, containing 5766 inhabitants.

MOGOO, a seaport of Laristan, in Persia, which has one of the most secure roadsteads in the Persian Gulf. It is formed by Cape Bostana to the eastward, and by Point Certes to the west. It is capable of containing the largest fleets, and the entrances are about ten miles asunder. It is eighty miles south of Lar.

MOGULS, a celebrated nation of Asia, whose conquests in former times were the most rapid and extensive of any people recorded in history. They themselves deduce their origin from Japhet, or, as they call him, *Japhis*, the son of Noah. His son Turk was, according to them, the first king, or khan, of those nations who are now known by the separate

denominations of *Turks*, *Tartars*, and *Moguls*; and the Tartars especially assert, that their proper designation is *Turks*. To this prince is attributed many of those inventions which barbarous nations commonly ascribe to their first sovereigns. He was succeeded by Taunak, in whose reign the whole posterity of Turk were divided into four large tribes, denominated the *ordas* of Erlat, Gialair, Kaugin, and Berlas or Perlas; from the last of which the famous Timour-Beg, or Tamerlane, was descended. From this time till that of Alanza Khan we meet with nothing remarkable. In the reign of Alanza, the Turks, being immersed in all kinds of luxury, universally apostatized into idolatry. Having two sons, Tartar and Mogul, he divided his dominions between them, and thus gave rise to the two empires of the Tartars and Moguls.

These two nations had not long existed before they began to make war upon each other; and after long contention, the event at last was, that Il Khan, emperor of the Moguls, was totally overthrown by Siuntz Khan, emperor of the Tartars; and so complete was the defeat that the Mogul nation seems to have been almost exterminated. Only two of Il Khan's family survived this disaster. These were Kajan his youngest son, and Nagos his nephew, who were both of the same age, and had both been married the same year. These two princes, with their wives, had been taken prisoners by Siuntz Khan, but found means to effect their escape to their own country, where they seized upon all the cattle which had not been carried off by the Tartars, an act that was easily done, as there were none to dispute the property with them; then stripping some of the slain, they took their clothes and retired into the mountains. They passed several mountains without much difficulty, and at last advanced to the foot of one exceedingly high, which had no way over it but a very small path made by certain animals, called, in the Tartar language, *archara*. This path they found themselves obliged to make use of, although it was so narrow and steep that only one could pass at a time, and he was in the most imminent danger of breaking his neck at the least false step. Having ascended the mountain on one side by this path, they descended by the same on the other; and were very agreeably surprised to find themselves in a most delightful tract, interspersed with rivulets and charming meadows, abounding with a vast variety of delicious fruits, and enclosed on all sides by inaccessible mountains, in such a manner as to shelter them from the future pursuits of the Tartars. Here they lived some time, and gave this beautiful country the name of *Irgana-kon*, in allusion to its situation; *irgana* signifying, in the old language of the Moguls, a valley, and *kon*, a steep height.

In process of time these two families increased greatly. Kajan, whose posterity was the most numerous, called his descendants *Kajath*; but the people springing from Nagos were divided into two tribes, one of which received the appellation of *Nagosler*, and the other that of *Durlagan*.

The two Mogul princes and their descendants lived in this place for more than four hundred years; but the latter having found it too narrow for them, meditated a return to the country from which their forefathers had been driven. For some time, however, this proved impracticable, as the path which conducted their ancestors had been long previously destroyed. At last they discovered that one part of the high mountain above mentioned was not very thick in a certain place; and also, that it consisted entirely of iron ore. To this, having before set fire to a layer of wood, and another of charcoal, placed along the foot of the mountain, they applied seventy large bellows, and at last melted the mountain in such a manner that an opening was made, large enough for a loaded camel to pass; and through this passage they all marched out with great joy.

The Moguls having thus issued as it were from a new

Moguls. world, overthrew the Tartars in their turn, and continued to form a considerable nation till the time of their great hero Temujin, afterwards called Genghiz Khan, whom they extol in the most extravagant manner. It is difficult, however, to say, at the time when Temujin made his appearance, how far the dominions of the Moguls extended, or in what estimation they were held by their neighbours. It seems to be pretty certain that great part of the vast region now known by the name of *Tartary* was then in a state of considerable civilization, and likewise extremely populous, as we find mention made of many cities which the Moguls destroyed; and the incredible multitudes whom they slaughtered abundantly prove the populousness of the country. On the east, the country of the Moguls and Tartars had the great desert which divides *Tartary* from China; on the west it had the empire of *Karazm*, founded by *Mahmoud Gazni*; and on the south were the countries now known by the name of *Hindustan*, *Siam*, *Pegu*, *Tonquin*, and *Cochin-China*. Thus it comprehended the eastern part of Modern *Tartary*, and all *Siberia*. This whole region was divided amongst a great number of *Aymacks* or *tribes*, who had each one or more khans, according as it happened to be more or less numerous, or divided into branches. Amongst these, that of the *Kara-its* was the most powerful. Their prince assumed the title of *Great Khan*, and, amongst the rest, the Moguls were tributary to him; but, according to the Chinese historians, both the one and the other were tributary to the emperor of *Kitay* or *Katay*.

China was divided into two parts; the nine southern provinces being in the hands of the Chinese emperors of the *Song* dynasty, who kept their court at *Hang-chew*, the capital of the province of *Chekyang*; and the five northern provinces, excepting part of *Shensi*, being possessed by the *Kin*, a people of Eastern *Tartary*, from whom are descended the *Manchoo* Tartars, who are at present masters of China. This vast dominion was named *Kitay* or *Katay*, and was divided into two parts; that which belonged to China was properly called *Kitay*; and the part which belonged to *Tartary* was called *Karakitay*, in which some even include the territories of the Moguls, *Kara-its*, and other tribes which form the subject of the present history. The western part of the empire of *Kitay* was possessed by a Turkish prince, who had lately founded there a new kingdom called *Hya*, and whose capital city was *Hya-chew*, now *Ninghya* in *Shensi*, from which the kingdom took its name. To the west of *Hya* lay *Tangut*, a country of great extent, and formerly very powerful, but at that time reduced to a low state, and divided amongst many princes, some of whom were subject to the emperor of *Hya*, and others to the emperor of China. All *Tartary* to the westward as far as the *Caspian Sea*, with the greater part of *Little Buckharia*, which then passed under the general name of *Turkestan*, was subject to *Ghurkhan*, *Khurkhan*, or *Kaver Khan*; to whom even the *Gazni* monarchs are said to have been tributary. This *Ghurkhan* had been prince of the Western *Kitan* or *Lyau*, who, when driven out of *Kitay* by the king, settled in *Little Buckharia*, and the country to the north, where they founded a powerful state about the year 1124.

Thus the Moguls, properly so called, had but a very small extent of empire which could be called their own, if indeed they had any, when Temujin made his appearance. This hero is believed by the Tartars to have been of divine origin, since his family could be traced no farther back than ten generations. The names and transactions of his predecessors are equally uncertain and unimportant. He himself, however, was born in the year 1163, and is said to have come into the world with congealed blood in his hands; whence it was prognosticated that he would be a great warrior, and obtain the victory over all his enemies.

Moguls. This prediction, if any such there was, Temujin most literally fulfilled. At the time of his father's decease, his subjects amounted to between thirty and forty thousand families; but of these about two thirds quickly deserted, and Temujin was left almost without subjects. When only thirteen years of age, he fought a bloody battle against these revolvers; but he was either defeated, or gained an indecisive victory, so that he remained in obscurity for twenty-seven years longer. His good fortune at last he owed to the friendship of *Vang Khan*, who ruled over a great number of Tartar tribes to the north of *Kitay*, and has been heard of under the name of *Prester John* amongst the Europeans. This prince took Temujin under his protection; and a rebellion having afterwards been raised against himself, Temujin was made his general, and the khan was kept in possession of his throne. Soon after this, Temujin subdued the tribes which had revolted from himself, and treated them with the utmost barbarity.

This happened in the year 1201; but *Vang Khan*, instead of continuing the friend of Temujin, now became jealous, and resolved to destroy him by treachery. With this view he proposed a marriage between Temujin's son *Juji* and his own daughter, and another between Temujin's daughter and his own son. Temujin was invited to the camp of *Vang Khan*, in order to celebrate this double marriage; but having received intelligence of some evil intention against him, he excused himself to *Vang Khan's* messengers, and desired that the ceremony might be put off to some other time.

A few days after the departure of these messengers, *Badu* and *Kishlik*, two brothers, who kept the horses of one of *Vang Khan's* chief domestics, came and informed Temujin, that the *Grand Khan*, finding he had missed his aim, was resolved to set out instantly, and to surprise him next morning, before he could suspect any danger. Temujin, alarmed at this intelligence, quitted his camp in the night time, and retired with all his people to some distance. He was scarcely gone when *Vang Khan's* troops arrived, and discharged an incredible number of arrows amongst the empty tents; but finding nobody there, they pursued Temujin in such haste that they fell into great disorder. In this condition they were suddenly attacked and routed by Temujin, after which ensued an open war with *Vang Khan*.

By this quarrel almost all the princes of *Tartary* were put in motion, some taking part with Temujin, and others with *Vang Khan*. But at last fortune declared in favour of the former. *Vang Khan* was overthrown in a battle, where he lost forty thousand men, and was obliged to fly for refuge to a prince named *Tayyan Khan*, who was Temujin's father-in-law, and his own enemy, and by whom he was ungenerously put to death. Temujin immediately began to seize on his dominions, great part of which voluntarily submitted; but a confederacy was formed against him by a number of *Vang Khan's* tributaries, at the head of whom was *Jamuka*, a prince who had already distinguished himself by his enmity to Temujin; and even *Tayyan Khan* himself was drawn into the plot, through jealousy of his son-in-law's good fortune. But Temujin was well prepared; and in the year 1204 he attacked *Tayyan Khan*, entirely routed his army, killed himself, and took *Jamuka* prisoner, whose head he caused instantly to be struck off; after which he marched against the other tribes who had conspired against him. These he quickly reduced; took a city called *Kashin*, where he put all to the sword who had borne arms against him; and subjugated all the *Mogul* tribes in 1205.

Temujin having now none to oppose him, called a general diet, which he appointed to be held on the first day of the spring in the year 1206; that is, on the day in which the sun entered *Aries*. To this diet were summoned all the great

Moguls. lords, both Moguls and Tartars; and in the mean time, to establish good order in the army, he divided his soldiers into bodies of ten thousand, a thousand, a hundred, and ten men, with their respective officers, all subordinate to the generals, or those who commanded the bodies of ten thousand; and these were to act under his own sons. On the day of holding the diet, the princes of the blood and great lords appeared dressed in white. Temujin, habited in the same manner, with his crown on his head, sat down on his throne, and was complimented by the whole assembly, who wished him the continuance of his health and prosperity. After this they confirmed the Mogul empire to him and his successors, adding all those kingdoms which he had subdued, the descendants of whose vanquished khans were deprived of all right or title to them; and after this he was proclaimed emperor with much ceremony. During this inauguration, a pretended prophet declared that he came from God to tell the assembly, that thenceforth Temujin should assume and bear the name of "Genghiz Khan," or "the Most Great Khan of khans;" prophesying also, that his posterity should be khans from generation to generation. This prophecy, which was no doubt prompted by Temujin himself, had a surprising effect on his subjects, who from that time concluded that all the world belonged of right to them, and even thought it a crime against heaven for any body to pretend to resist them.

Genghiz Khan having now reduced under his subjection all the wandering tribes of Moguls and Tartars, began to think of subjugating those countries to the south and south-west of his own, where the inhabitants were much more civilized than his own subjects; and the countries being full of fortified cities, he must of course expect to meet with more resistance. He began with the emperor of Hya, whose dominions he invaded in 1209, and who at last submitted to become his tributary. But in the mean time Genghiz Khan himself was supposed to be tributary to the emperor of Kitay, who, in 1210, sent him an officer demanding the customary tribute. This was refused with the utmost indignation, and a war commenced, which ended only with the dissolution of the empire of Kitay.

In the year 1216, Genghiz Khan resolved to carry his arms westward, and therefore left his general Muchuli to pursue his conquests in Kitay. In his journey westward he overthrew an army of three hundred thousand Tartars who had revolted against him; and in 1218 he sent ambassadors desiring an alliance with Mohammed Karazm Shah, emperor of Gazna. His ambassador was haughtily treated; the alliance was, however, concluded, but soon afterwards broken, through the treachery, as it is said, of the Karazmian monarch's subjects. This brought on a war, attended with the most dreadful devastations, and which ended with the entire destruction of the empire of Karazm or Gazna.

After the reduction of Karazm, part of the Moguls broke into Iran or Persia, where they also made large conquests, whilst others of their armies invaded Georgia and the countries to the west; in both cases committing such enormities that the Chinese historians say both men and spirits burst with indignation. In 1225, Genghiz Khan returned to Hya, where he made war upon the emperor for having sheltered some of his enemies. The event was, that the emperor fell in battle, and his kingdom was conquered, or rather destroyed; but this was the last exploit of the cruel conqueror, who died in 1227, as he marched to complete the destruction of the Chinese.

The Mogul empire, at the death of Genghiz Khan, extended over a prodigious tract of country, being more than eighteen hundred leagues in length from east to west, and upwards of a thousand in breadth from north to south. Its princes, however, were still insatiable, and pushed their conquests upon all sides. Oktay was acknowledged em-

peror after Genghiz Khan, and had under his immediate government Mogulestan, or the country of the Moguls properly so called, with Kitay, and the countries eastward to the Tartarian Sea. Jagaty, his brother, governed under him a great part of the western conquests. The country of the Kipjacks, and others to the east and north-east, north and north-west, were governed by Batu or Patu, the son of Jujji, who had been killed in the wars; whilst Tuli or Toley, another son of Genghiz Khan, had Khorassan, Persia, and that part of India which had been conquered. On the east side the Mogul arms were still attended with success; not only the empire of Kitay, but the southern part of China, was conquered. On the west side matters continued much in the same way till the year 1254, when Magu, or Menkho, the fourth khan of the Moguls, raised a great army, which he gave to his brother Hulaku or Hulagu, in order to extend his dominions westward. In 1255 he entered Iran, where he suppressed the Ismaelians or Assassins, of whom an account is given under the article ASSASSINS; and two years afterwards he advanced to Bagdad, which he took, and cruelly put to death the caliph, treating the city with no more lenity than the Moguls usually treated those places which fell into their hands. Every thing was put to fire and sword; and in the city and its neighbourhood the number of slain, it is said, amounted to one million six hundred thousand. The next year he invaded Syria. The city of Damascus was delivered up, and, as it made no resistance, the inhabitants were spared; but Aleppo being taken by storm, a greater slaughter ensued there than had taken place at Bagdad, not even the children in their cradles being spared. Some cities of this country revolted the next year, or the year after; but having again fallen into the hands of the Moguls, they were plundered, and the inhabitants butchered without mercy, or carried into slavery.

Hulaku died in 1264, and at his death we may fix the greatest extent of the Mogul empire. It now comprehended the whole of the continent of Asia, excepting part of Hindustan, Siam, Pegu, Cochin-China, and a few of the countries of Lesser Asia, which had not been attacked by them; and during all these vast conquests no Mogul army had ever been conquered, except one by Jaloloddin. From this period, however, the empire began to decline. The ambition of the khans having prompted them to invade the kingdoms of Japan and Cochin-China, they were miserably disappointed in their attempts, and lost a great number of men. The same ill success attended them in Hindustan, and in a short time this mighty empire broke into several smaller ones. The governors of Persia, being of the family of Genghiz Khan, owed no allegiance to any superior; and those of Tartary were similarly circumstanced. The Chinese threw off the yoke, and thus the continent of Asia wore much the same face that it had done before Genghiz Khan began his conquests.

The successors of Hulaku reigned in Persia till the year 1335; but that year Abusaid Khan, the eighth from Hulaku, having died, the affairs of that country fell into confusion for want of a prince of the race of Genghiz Khan to succeed to the throne. The empire, therefore, was divided amongst a great number of petty princes, who fought against each other almost without intermission, till, in the year 1369, Timour Beg or Tamerlane, one of these princes, having conquered a number of others, was crowned at Balkh, with the pompous title of "Sahib Kharan," that is, "the emperor of the age, and the conqueror of the world." As he had just before taken that city, and destroyed one of his most formidable rivals who had shut himself up in it, the new emperor began his reign with beheading some of the inhabitants, imprisoning others, burning their houses, and selling the women and children as slaves. In the year 1370 he crossed the Sihun, made war on the Getes, and attacked

Moguls. Karazm. Next year he granted a peace to his enemies; but two years after, he again invaded the country of the Getes; by the year 1379 he had fully conquered that country, as well as Khorassan; and from that time he continued to extend his conquests in much the same manner as Genghiz Khan had done, though with less cruelty. In 1387 he had reduced Armenia, Georgia, and all Persia; the conquest of which last was completed by the reduction of Ispahan, seventy thousand of the inhabitants of which were slaughtered on account of a sedition raised by some rash or evil-disposed persons.

After the reduction of Persia, Timour turned his arms northward and westward, subduing all the countries to the Euphrates. He took the city of Bagdad; subdued Syria; and having ravaged great part of Russia, returned to Persia in 1396, where he splendidly feasted his whole army. In 1398 he crossed the Indus on the 17th of September, invaded Hindustan, reduced several fortresses, and made a vast number of captives. However, as he was afraid that, in case of any emergency, these prisoners might take part with the enemy, he gave orders to his soldiers to put all their Indian slaves to death; and, in consequence of this inhuman order, more than one hundred thousand of these poor wretches were slaughtered in less than an hour.

In the beginning of the year 1399, Timour was met by the Indian army, whom, after a desperate battle, he defeated with great slaughter, and soon afterwards took the city of Delhi, the capital of the country. Here he seated himself on the throne of the Indian emperors; and here the scherifs, kadis, and the principal inhabitants of the city, came to make their submission, and begged for mercy. The tame elephants and rhinoceroses were likewise brought to kneel before him as they had been accustomed to do to the Indian emperors, and made a great cry as if they implored his clemency. These war elephants, one hundred and twenty in number, were, at his return, sent to Samarcand, and to the province where his sons resided. After this, at the request of the lords of the court, Timour made a great feast, at which he distributed presents to the princes and principal officers.

Delhi at this time consisted of three cities called Seyri, Old Delhi, and Jehan Penah. Seyri was surrounded with a wall in the form of a circle. Old Delhi was also walled, but much larger, lying south-west of the other. These two parts were joined on each side by a wall; and the third, situated between them, was called Jehan Penah, which was larger than Old Delhi. Penah had ten gates; Seyri had seven, three of which looked towards Jehan Penah; and this last had thirteen gates, six to the north-west, and seven to the south-east. Every thing seemed to be in a quiet posture, when, on the 12th of January 1399, the soldiers of Timour, being assembled at one of the gates of Delhi, insulted the inhabitants of the suburbs. The great emirs were ordered to put a stop to these disorders; but their endeavours proved ineffectual. The sultanas having a curiosity to see the rarities of Delhi, and particularly a famous palace adorned with one thousand pillars, built by an ancient king of India, went with all the court into the city; and the gate being on that occasion left open for every body, above fifteen thousand soldiers got in unperceived. But there was a far greater number of troops in a large place between Delhi, Seyri, and Jehan Penah, who committed great disorders in the two last cities. This made the inhabitants in despair fall on them; and many, setting fire to their houses, burnt their wives and children. The soldiers, seeing this confusion, did nothing but pillage the houses, whilst the disorder was increased by the admission of more troops, who seized the inhabitants of the neighbouring places that had fled thither for shelter. The emirs, to put a stop to this mischief, caused the gates to be shut; but they were quickly opened by the soldiers

within, who rose in arms against their officers, so that by the morning of the 13th the whole army had entered, and this great city was totally destroyed. Some soldiers carried out as many as an hundred and fifty slaves, men, women, and children; nay, some of their boys had twenty slaves a piece to their share. The other spoils, in jewels, plate, and manufactures, were immense; for the Indian women and girls were adorned with precious stones, and had bracelets and rings on their hands, feet, and even toes, so that the soldiers were loaded with them. On the 15th, in Old Delhi, the Indians retired into the great mosque to defend themselves; but being attacked there by the Tartars, they were all slaughtered, and towers erected with their heads. A dreadful carnage now ensued throughout the whole city, and several days were employed before the inhabitants could be made to quit it entirely; and as they went forth, the emirs took a number of them into their service. The artisans were also distributed amongst the princes and commanders; all but the masons, who were reserved for the emperor, in order to build him a spacious stone mosque at Samarcand.

After this terrible devastation, Timour marched into the different provinces of Hindustan, everywhere defeating the Indians who opposed him, and slaughtering the Ghebres or worshippers of fire. On the 25th of March he set out on his return, and on the 9th of May he arrived at Samarcand. In a few months after his arrival he was obliged to undertake an expedition into Persia, where affairs were in the utmost disorder on account of the misconduct of his son, whom he had appointed sovereign of that empire. Here Timour soon settled matters, after which he again set out on an expedition to the westward, reduced many places in Georgia which had not submitted before, and invaded and conquered Syria. At the same time he quarrelled with Bajazet the Turkish sultan, then engaged in an enterprise against Constantinople, in which he would probably have succeeded had not Timour interposed. At first the cause of this quarrel was, that Bajazet had demanded tribute from a prince who was under Timour's protection, and is said to have returned an insulting answer to the Tartar ambassadors who were sent to him on that account. Timour, however, who was an enthusiast in the cause of Mahomedanism, and considered Bajazet as engaged in the cause of heaven when besieging a Christian city, was very unwilling to disturb him in so pious an enterprise, and therefore undertook several expeditions against the princes of Syria and Georgia, in order to give the Turkish monarch time to cool and return to reason. Amongst other places he again invested the city of Bagdad, which had cast off its allegiance to him; and having taken it by assault, he made such a dreadful massacre of the inhabitants, that one hundred and twenty towers were erected with the heads of the slain. In the mean time Bajazet continued to give fresh provocation, and even protected one Kara Yussuf, a robber, who had openly insulted the caravan of Mekka, so that Timour at length resolved to make war upon him. The sultan, however, foreseeing the danger of bringing such a formidable enemy against himself, thought proper to ask pardon, by a letter, for what was past, and to promise obedience to Timour's will for the future. This embassy was graciously received; and Timour returned for answer, that he would forbear hostilities, provided Bajazet would either put Kara Yussuf to death, or send him to the Tartar camp, or expel him from his dominions. Along with the Turkish ambassadors he sent one of his own, telling Bajazet that he would march into the confines of Anatolia, and there wait his final answer.

Though Bajazet had seemed at first willing to come to an agreement with Timour, and evidently dreaded his superior power, yet he now behaved in such an unsatisfactory manner that the Tartar monarch desired him to prepare for

Mohair
Mohawk

war; upon which he raised the siege of Constantinople, and having met Timour with an army greatly inferior to the Tartars, was utterly defeated and taken prisoner. According to some accounts he was treated with great humanity and honour; whilst others inform us that he was shut up in an iron cage, against which he dashed out his brains the following year. At any rate, it is certain that he was not restored to liberty, but died in confinement.

This victory was followed by the submission of many places of Asia Minor to Timour; and the Greek emperor owned himself tributary, as did likewise the sultan of Egypt. After this Timour once more returned to Georgia, which he cruelly ravaged; and then he marched to Samarcand, where he arrived in the year 1405. Here, being now an old man, this mighty conqueror began to look forward to that state which at one time or other becomes the dread of all living creatures; and Timour, in order to quiet the remorse of his conscience, came to a curious resolution, which he communicated only to his intimate friends. This was, that "as the vast conquests he had made were not obtained without some violence, which had occasioned the destruction of a great number of God's creatures, he was resolved, by way of atonement for his past crimes, to perform some good action, namely, to make war on the infidels, and exterminate the idolaters of China." This atonement, however, he did not live to accomplish, for he died the same year, of a burning fever, in the seventy-first year of his age and thirty-sixth of his reign.

Upon the death of Timour, his empire fell immediately into great disorder, and the civil wars continued for five or six years; but at last peace was restored, by the settlement of Shah Rukh, Timour's son, on the throne. The latter, however, did not enjoy the empire in its full extent, or indeed much above one half of it; having only Karazm, Khorassan, Kandahar, Persia, and part of Hindustan. Neither was he, though a brave and warlike prince, able to extend his dominions; yet he transmitted them to his son Ulug-Beg, who proved a wise and learned monarch, and is famous for the astronomical tables which he caused to be composed, and which are well known at this day. Ulug-Beg was killed in 1448, by his son Abdallatif, who six months after was put to death by his own soldiers. Upon the death of Abdallatif, Abdallah, a grandson of Shah Rukh, seized the throne; but, after reigning one year, he was expelled by Abusaid Mirza, the grandson of Miran Shah, the son of Timour. His reign was one continued scene of wars and tumults, until at last he was defeated and taken prisoner by one Hassan Beg, who put him to death in 1468. From this time we may look upon the empire of Timour as entirely dissolved.

On the death of the above-mentioned monarch, his son Baber succeeded him, but was soon driven out by the Usbeck Tartars; after which he resided some time in Gazna, whence he made incursions into Hindustan, and at length became master of the whole empire, excepting the kingdoms of Dekkan, Guzerat, and Bengal. See HINDUSTAN.

MOHAIR, in commerce, the hair of a particular kind of goat frequent about Angora, in Turkey, the inhabitants of which are all employed in the manufacture of camblets made of this material.

Some give the name of *mohair* to the camblets or stuffs made of this hair, and of which there are two kinds; the one smooth and plain, and the other watered like tabbies. The difference between the two consists only in this, that the latter kind is calendered, and the other not. There are also mohairs both plain and watered, the woof of which consists of wool, cotton, or thread.

MOHAWK, a large branch of the Hudson, or North River, of the state of New York, in North America. It rises in the north-east part of Oneyda county, about twenty miles north of Rome, to which place it runs in nearly a

south direction, and then turns eastward towards the Hudson, which it enters by several mouths between Troy and Waterford, after a course of about one hundred and thirty-five miles. The stream of the Mohawk is unequal, having many breaks and rapids, and two considerable falls. With the aid of canals, however, it is rendered navigable from Schenectady to Rome; but it chiefly serves the purposes of navigation by supplying water to the canals in its immediate vicinity. It is remarkably well adapted for supplying water-power for all manufacturing purposes. The land upon its borders is rich, and fitted for all agricultural purposes. The banks of this river were originally peopled by the Mohawks, an Indian tribe remarkable for courage and ferocity.

MOHILEW, a province of the European Russian empire. It is situated in N. lat. from 51. 58. to 55. 13., and in E. long. from 28. 47. to 32. 53., and is bounded on the north by Witepsk, on the north-east by Smolensk, on the south-east and south by Tschernigow, and on the west by Minsk. It contains 45,008 square wersts, or 17,978 square miles. It is divided into twelve circles, and contains 1,084,600 inhabitants, who live in twelve cities, fifty-five towns, and so great a number of small villages and farms, that they have not been accurately ascertained. There is a subdivision into a kind of Greek parishes, each surrounding the 310 churches of that religion. Mohilew is one of the districts which was taken from Poland in the year 1772, and, with Witepsk, formed one province under the name of White Russia; but, in 1802, a division was made into two provinces, the one called that of Witepsk, and the other that of Mohilew. The people of this province, from being a mixture of Russians and Poles, have formed for themselves a peculiar dialect, compounded of the language of these two races, with an intermixture of Latin, Moldavian, and German. The greater part of the inhabitants adhere to the orthodox Greek church, but many are of the united Greek religion; and there are many Catholics, who have an archbishop, and several churches and monasteries. There are also 40,000 Jews, who have synagogues in most of the towns. The province is generally a level plain, intersected by numerous streams; and the soil, though for the most part sandy, is moderately fertile. More corn is grown than the consumption requires in almost every year, and, after a deficient harvest in Poland and Germany, large supplies are furnished to these countries. The woods are extensive, and yield large stores of timber of every description required either for fuel or for the construction of houses or ships. The chief productions, besides corn and wood, are black cattle, sheep; wool, hemp and flax, and their seed; honey, wax, bacon and bristles, with tallow and hides. These are conveyed both to the Baltic and to the Black Sea by means of the navigable rivers. Some iron is found, which is used for making scythes and other agricultural implements; but the mines do not yield a quantity sufficient for the demand.

MOHILEW, a city, the capital of the Russian province of that name, and of the circle in which it stands. It is situated on the river Dnieper, 564 miles from St Petersburg. It is surrounded with walls, and has broad, well-paved streets, one square, sixteen churches, four monasteries, 2100 houses, and 16,900 inhabitants. From its situation on a great river, it is the chief place where the commercial transactions of the province centre, and whence goods are transmitted to Riga, Königsberg, Memel, and Dantzic. Long. 48. 4. 30. E. Lat. 53. 54. N.

MOHILEW, a circle of the Russian province of Podolia, which extends in N. lat. from 48. 14. to 49. 5., and in E. long. from 27. 45. to 28. 19. The river Dniester flows upon the southern side, and conveys the water of the smaller streams to the Black Sea. The circle produces excellent wheat and other corn, with tobacco, hemp, and flax, in abundance. The capital, a city of the same name, is situ-

Mohurbunge
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Moiivre.

ated on the Dniester, 1106 miles from St Petersburg. It contains several Greek and Catholic churches, 1176 houses, and 7200 inhabitants. Long. 35. 41. E. Lat. 48. 25. N.

MOHURBUNGE, a district of Orissa, in the province of Hindustan, situated between the 21st and 33d degrees of N. lat. It is a hilly, unfertile district, and derives its revenues chiefly from the Hindu pilgrims who visit the temple of Juggernaut.

MOIDORE, a Portuguese gold coin, of the value of L.1. 7s. sterling.

MOIRA, a post-town of Ireland, in the county of Down, ninety miles north from Dublin. It has a handsome church, two dissenting meeting-houses, and a free school. Moira Castle is situated in the vicinity of the town. The population in 1831 was 787. Long. 6. 6. W. Lat. 54. 27. N.

MOISSAC, an arrondissement of the department of the Tarn and the Garonne, in France, 332 square miles in extent. It comprehends six cantons, which are divided into forty-nine communes, with a population in 1836 of 62,735 persons. The capital is the city of the same name, situated in a fertile district, through which flows the Tarn, which soon after joins the Garonne. It contains 10,618 inhabitants, who are chiefly occupied in trading with Bordeaux, to which city it conveys flour, oil, wool, wine, and a great deal of saffron, for the trade with the colonies. Long. 1. 17. E. Lat. 44. 8. N.

MOIVRE, ABRAHAM DE, a very learned mathematician, was born in the year 1667, at Vitry in Champagne, in France, where his father was a surgeon. After the revocation of the edict of Nantes, he proceeded to England. Before he left France, he had commenced the study of the mathematics; and having perfected himself in that science in London, he was obliged, by necessity, to teach it. But Newton's *Principia*, which accidentally fell into his hands, showed him how little progress he had made in a science of which he thought himself master. From this work he acquired a knowledge of the geometry of infinites with as great facility as he had learned the elementary geometry; and in a short time he was enabled to rank with the most celebrated mathematicians. His success in these studies procured him a seat in the Royal Society of London, and in the Academy of Sciences at Paris. His merit was so well understood in the former, that he was thought capable of deciding in the famous dispute between Leibnitz and Newton concerning the differential calculus. He published a Treatise on the Doctrine of Chances in 1738, and another on Annuities in 1752, both extremely accurate. The Philosophical Transactions contain many interesting memoirs of his composition. Some of these treat of the method of fluxions; others of the lunula of Hippocrates; others of physical astronomy, in which he resolved many important problems; and others of the analysis of games of chance, in which he followed a different course from that of Montmort. Towards the close of his life he lost both his sight and his hearing; and the demand for sleep became so great that he required twenty hours of it in a day. He died at London in 1754, aged eighty-seven. His knowledge was not confined to the mathematics; and he retained to the last a taste for polite literature. He was intimately acquainted with the best authors of antiquity, and was frequently consulted about difficult passages in their works. Rabelais and Molière were his favourite French authors; indeed he had them by heart, and one day observed to an acquaintance, "that he would rather have been Molière than Newton." He recited whole scenes of the *Misanthrope*, with that delicacy and force with which he remembered to have heard them recited at Paris seventy years before, by Molière's own company. The character, indeed, was somewhat similar to his own. He judged severely of mankind, and could never conceal his disgust at the conversation of a fool, or his aversion to cunning and

dissimulation. He was free from the affectation of science, and no one could have known that he was a mathematician except from the accuracy of his thoughts. His conversation was general and instructive. Whatever he said was well digested and clearly expressed. His style possessed more strength and solidity than ornament and animation; but he was always correct, and he bestowed as much pains on his sentences as on his calculations. He could never endure any bold assertions or indecent witticisms against religion.

MOLA, a city of the kingdom of Naples, in the province of Bari. It stands on the sea-shore, but has no good haven. It contains 7664 inhabitants, many of whom are occupied in the fisheries, and others in the cultivation of vines and olive trees.

MOLA SALSA, in *Antiquity*, was barley parched, and afterwards ground to meal or flour, after which it was mixed with salt and frankincense, with the addition of a little water. Thus prepared, it was sprinkled between the horns of the victim before it was killed in sacrifice. This act was called *immolatio*, and was common to both Greeks and Romans; with this difference, that the *mola* of the Romans was of wheat.

MOLD, or MOULD, a town of the county of Flint, in North Wales, in the hundred of its own name, 207 miles from London. It consists of one long and wide street, and has a market on Saturday. It is an ancient borough, and, in conjunction with Rhyddlan, Overton, Caerwis, Caergwreley, St Asaph, and Holywell, returns one member to the House of Commons. Of late extensive cotton-works have been established at this place. The population amounted in 1801 to 4235, in 1811 to 5083, in 1821 to 6268, and in 1831 to 8086.

MOLDAVIA, a principality nominally under the Turkish government. It was the ancient Transalpine Dacia, and received the name it now bears in the fourteenth century, from the principal river which drains it. It extends in east longitude from 25. 13. to 28. 26., and in north latitude from 45. 24. to 48. 17., occupying 17,017 square miles. It is bounded on the north and the east by the Russian province of Podolia, from which it is divided by the river Pruth, and in part by the Danube; on the south by Wallachia, and on the south and west by the Austrian provinces of Transylvania and Gallicia. Its great divisions are into Upper and Lower Moldavia, the former being subdivided into four, and the latter into nine circles. It is difficult to determine the precise amount of the population; some authorities state it as low as 300,000, and others, especially Camperhausen, make it to be near 600,000, since a part of the country has been transferred to Russia. The people are mostly of the Wallachian race, but there are intermixed with them many Greeks, Armenians, Jews, gipsy slaves, and Hungarians. The prevailing religion is that of the Greek church, which has an archbishop, three bishops, 87 monasteries, and 931 churches. The Catholics do not exceed 12,000, and have 13 churches, forming a part of the diocese of Nicopoli. There is a seminary for education at the capital, Jassy, but very little attention is paid to the instruction of the mass of the people. The government is conducted by a delegate from Turkey, called a waiwode, who purchases the office. He must be a Greek; and, after being installed, he has a most unlimited degree of power, by the exercise of which he seeks to reimburse himself for the price of his purchase. This viceroy, as well as his wife, is considered as of princely rank, and maintains a court and army; but he is subject to sudden recall, and to heavy payments, at the will of the capricious or greedy cabinet of Constantinople. There is scarcely any written law; but what is by courtesy called justice is administered by the divan, of which the Archbishop of Jassy is president, and the other members are the several higher public function-

Mola
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Moldavia.

Mole
Molière.

aries. In each circle there is an inferior court, from which appeals can be made to the divan. The waiwode has a body-guard of 400 men, and a force of 3000 military, chiefly Arnaut Greeks, who are regularly trained.

The Carpathian Mountains, on the western frontier, send out spurs, which gradually diminish in height as they approach the eastern side, and present the appearance of a beautifully undulating country. The soil is stony on the east, but gradually improves in fertility as it approaches the rivers; and the greater part is abundantly productive, amply rewarding the labour which is applied to it, notwithstanding the excessive heat of the summers, and the intense cold of the winters. The corn is excellent, especially the summer or hard wheat. The wine is good, and produced in abundance. Excellent cattle are fattened in the meadows; and good flax, hemp, honey, wax, and all kinds of fruits, are most abundant. There is little of trade or manufactures, as each family produces and consumes the necessities of life in filth and idleness, and seems to require none of the gratifications of civilized man, whilst they indulge all the lower passions of our nature with little moral restraint.

MOLE, in *Architecture*, a massive work formed of large stones laid in the sea by means of coffer-dams, extended either in a right line or an arc of a circle, before a port, which it serves to close; to defend the vessels in port from the impetuosity of the waves, and to prevent the passage of ships without leave. It is frequently fortified.

MOLE is also sometimes used to signify the harbour itself, which it serves to form and defend.

MOLE (*moles*), amongst the Romans, was also used for a kind of mausoleum, built in the manner of a round tower on a square base, insulated, encompassed with columns, and covered with a dome. The mole of the Emperor Hadrian, now the castle of St Angelo, was the greatest and most stately of all the moles. It was crowned with a brazen pine-apple, in which was a golden urn containing the ashes of the emperor.

MOLFETTA, a city of the kingdom of Naples, in the province of Bari. It is situated on the sea-shore, and has a harbour, which is fit only for the reception of small vessels, but from it an extensive fishery is carried on. It is a place of various manufactures, each upon a small scale. The most considerable is the refining of saltpetre on account of the government, which yields about 10,000 quintals yearly. This city is the seat of a bishop, who has a handsome cathedral. There are six other churches and five monasteries, and also a collegiate institution for the education of the clergy. The population amounts to 11,496.

MOLIERE, JEAN-BAPTISTE POQUELIN, the most celebrated comic writer of France, was born at Paris on the 15th of January 1622. He was the son of Jean Poquelin, a merchant-upholsterer, and of Marie Cressé, whose father followed the same calling. Being designed by his parents to succeed them in their business, he was early employed in assisting them; and, at the age of fourteen, all he had acquired was a little reading, writing, and arithmetic. Fortunately he had a grandfather, who, being a lover of plays, used sometimes to take the boy along with him to the Hôtel de Bourgoyne. This was sufficient to inspire him with a distaste for his situation, and a desire to acquire that instruction of which he felt that he had been deprived. With much difficulty he prevailed on his parents to permit him to study, and he was sent as a day-scholar to the College of Clermont. Circumstances the most favourable to his fortune and his genius attended him in that seminary. He had as his class-fellow Armand de Bourbon, Prince of Conti, whose affectionate protection became afterwards useful to him upon more than one occasion. Another who followed the same course of study was Chapelle, the natural son of Lhuillier, a rich magistrate,

who had appointed as his preceptor the celebrated Gassendi, and associated with him as the companion of his studies, Bernier, then a poor child, but afterwards famous for his travels in India. Gassendi, struck with the happy disposition of young Poquelin, admitted him to the private lessons which he gave to his two pupils; a favour which was equally enjoyed by Cyrano de Bergerac, who did not profit quite so much by the opportunity thus afforded him.

From the conversations of Gassendi, who had combated, and often with success, Aristotle and Descartes, the two great rival powers of ancient and modern philosophy, Poquelin contracted the habit of not submitting his reason to any other authority than that of demonstrated truth. The ethical system of Epicurus, almost equally calumniated by his adversaries and his followers, was that which Poquelin then adopted, and which he ever afterwards professed. But his studies were destined soon to experience an interruption. Poquelin the father held the office of domestic upholsterer to the king; but being prevented by bad health from discharging its duties, the son, who had obtained the reversion of the situation, was obliged to attend Louis XIII. in his journey to Narbonne in the year 1641. Having returned with the court to Paris, his passion for the stage, which had first induced him to study, revived more strongly than ever. It has been said by some that he studied law for a time, and that he was even called to the bar. But this seems at least doubtful; or, if true, he must soon have abandoned his legal studies for those more attractive and fascinating pursuits in which he afterwards attained unrivalled eminence, and became the restorer of genuine comedy in France. The passion of Cardinal Richelieu for dramatic amusements had communicated itself to the nation; and everywhere in the capital private theatres were opened, where Rotrou and Desmarets, Corneille and Scudéry, were indiscriminately applauded. Poquelin assembled several young persons who had, or thought they had, a talent for declamation; and this society, which soon eclipsed all the others, was called the *Illustre Théâtre*. It was then that Poquelin resolved to follow his vocation, assumed the name of Molière, in order, as it should seem, that his parents might not have to reproach him with prostituting their name on the boards of a playhouse.

But the troubles of the Fronde interrupted the amusements of the theatre, and during this ridiculous tempest Molière disappeared; nor did he show himself again until the royal authority had reconquered its sway by transactions more powerful than arms. In this interval, extending from 1648 to 1652, he was probably occupied with the composition of some of those pieces which were afterwards exhibited to the public. His first regular production was the *Etourdi*, or Blunderer, which was represented at Lyons in 1653. Upon his arrival in that city, he had found another company of comedians, whom the public, however, promptly abandoned for his, and the principal performers of which then attached themselves to his fortunes, never more to separate. With this reinforcement he repaired to Beziers, where his old class-fellow, the Prince of Conti, was holding the states of Languedoc. Being specially instructed to amuse the city, the assembly, and the prince, he brought out in succession all the pieces in his little repository, which had just been enriched with the *Dépit Amoureux*. The prince, delighted with his wit and his zeal, offered to employ him as his secretary; but this he declined, observing, "I am a tolerable author, but I should make a very bad secretary." Having continued for some time his strolling performances in the south of France, he at length approached the capital, to which he was attracted by the secret hope of better fortune and greater fame; and when he actually returned thither in the year 1658, he again obtained the protection of his august college-companion, and through it acquired still more elevated patronage, name-

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ly, that of Monsieur, brother of the king, and also the favour of the king himself. It was under their auspices, and in their presence, that, on the 3d of November 1658, he opened that theatre which, in less than fifteen years, he enriched with more than thirty works, the half of which are masterpieces. Paris, which was now appealed to, confirmed the judgment of the provinces, and in the capital the *Etourdi* and the *Dépit Amoureux* were as successful as they had been in the south of France. On entering upon this new career, he had no other guide than his genius; but it proved all-sufficient.

The *Précieuses Ridicules* appeared in 1659, and at once struck with consternation those haughty coteries where affectation perverted at once the understanding and the feelings, and whose jargon infested literature as well as society. This was succeeded by the *Cocu Imaginaire*, in which he combated Scarron with his own weapons, and succeeded, by manners more true, a gaiety more natural, and a buffoonery in better taste. *Don Garcie de Navarre*, a heroic comedy, imitated from the Spanish, was but coldly received; but the *Ecole des Maris*, a comedy at once of manners, character, and intrigue, and of which the *Adelphi* of Terence had furnished the fundamental idea, was completely successful. The *Fâcheux* was produced the same year, 1661, and was played at Vaux in presence of Louis XIV. a few days before that monarch caused to be arrested, and imprisoned for the rest of his life, the minister who then entertained him. The *Ecole des Femmes* appeared in 1662, and, as might have been expected, excited a violent sensation, during the prevalence of which the author was assailed on all sides, and with every species of abuse; but in his *Critique de l'Ecole des Femmes*, which came out in 1663, he took ample vengeance on the envious fools and prudes who had leagued together to vilify that masterpiece. The same year he produced the *Impromptu de Versailles*, by way of reprisal on Boursault, who had attacked him in an impudently satirical piece, entitled *Le Portrait du Peintre*. The *Marriage Forcé*, 1664, is drawn from Rabelais, whom Molière, like La Fontaine, freely put in requisition; and, the same year, he composed the *Princesse d'Elide*, the subject of which belongs to the Spanish theatre. In 1665, Molière produced his *Festin de Pierre*, and also *L'Amour Médecin*, which last, he says, was proposed, written, learned, and represented in five days. The following year he brought out first the *Misanthrope*, and next *Le Médecin malgré lui*, the subject of which is taken from one of the old Fabliaux.

In 1677, besides the *Fagotier*, and *Le Sicilien, ou l'Amour Peintre*, he conceived and executed the *Tartuffe*, one of the boldest and best of his compositions. The idea of bringing upon the stage religious hypocrisy, in an age when devotion was the mode, certainly evinced no ordinary hardihood on the part of the incomparable writer; but, notwithstanding, he triumphed over all opposition. "Les faux dévots," says one of his French biographers, "furent frappés de terreur; des hommes vraiment pieux en conçurent des vives alarmes; ils ne voyaient pas sans horreur le profane théâtre s'arroger, pour ainsi dire, un droit de juridiction en matière sacrée. Et dans ce zèle ardent d'un comédien contre un vice dont l'église gémissait en secret, ils n'apercevaient qu'une envie mal déguisée d'insulter à la vertu même dont ce vice empruntait les dehors. Quand on songe au nombre, à la puissance, des personnes que les calculs d'un odieux intérêt ou les erreurs d'un zèle respectable avaient liguées contre le *Tartuffe*, on ne peut être surpris des difficultés qu'éprouva la représentation; on doit l'être seulement que Molière soit parvenu à les surmonter." In 1668, he produced the *Amphitryon* and *L'Avare*, both imitated, and in part borrowed, from Plautus, and also *George Dandin*, a comedy; in 1669, *Pourceaugnac*, a farce, containing some scenes high-

ly comic, and the *Amans Magnifiques*, in which he ridicules the chimeras of astrology, with which many persons were then infatuated; and, in 1670, the *Bourgeois Gentilhomme*, of which the king said, "Vous n'avez encore rien fait qui m'ait tant diverti, et votre pièce est excellente." The *Fourberies de Scapin*, *Psyché*, and *La Comtesse d'Escarbagnas*, came out in 1671; and the following year he produced the *Femmes Savantes*, which was condemned before being heard, as much from apprehension as any other cause. His last comedy was *Le Malade Imaginaire*, 1673, which terminated the dramatic career of Molière.

Upon the day when this piece was acted for the fourth time, the author suffered severely from a pain in the chest, and his friends endeavoured to persuade him not to play. He persisted, however, and, in the entertainment of the piece, at the moment when he pronounced the word *Juro*, he was seized with convulsions, which he endeavoured in vain to conceal under a forced smile. He was removed to his house, where some hours afterwards he died from a vomiting of blood, which appears to have suffocated him. His death took place in the evening of the 17th of February 1673, in the fifty-second year of his age. As he had died in a state of excommunication, the curate of Saint-Eustache, his parish, refused him ecclesiastical sepulture. "What!" exclaimed his widow, "do they here refuse him sepulture? In Greece they would have raised altars in his honour." This objection was overcome, however, and his remains were interred in the cemetery of Saint-Joseph.

All that we learn respecting the personal character of Molière is greatly to his honour. Happy in the society of his friends, he was respected and beloved by his equals; and, though courted by the great, he retained to the last the original simplicity of his character. Marshal Vivonne, the great Condé, and even Louis XIV., treated him with that familiarity which considers the distinction of merit as placing its possessor upon a level with the highest accidents of birth or fortune; but this flattering notice neither corrupted his heart nor misled his understanding. He was kind, generous, and liberal alike of his means and his influence; he had an honest consciousness of superiority, which exalted him above envy, whilst his disposition prompted him to do all the good in his power. He assisted Racine in his difficulties, and, by the encouragement he gave to that poet, proved instrumental in bringing forward a genius destined to become the glory of the French stage. The occupation of Molière in lashing the vices and follies of his time naturally drew upon him the indignation of those who had smarted under the poignant keenness of his wit; throughout his whole career, indeed, he had been pursued by satirical libels; and even after his death, his enemies, carrying their resentment beyond the grave, assailed his memory, in sarcastic epitaphs. The author of one of these pieces had the ill fortune, or the stupidity, to offer it to the great Condé: "Plût à Dieu," said the hero sternly, "que celui dont tu me présentes l'épithaphe, fût en état de me présenter la tienne!" The only one of these productions possessing any point is the following:—

Roscius hic situs est tristi Molierus in urna,
Cui genus humanum ludere, ludus erat.
Dum ludit mortem, mors indignata jocantem
Corripit, et mimum fingere sæva negat.

The French nation has with one voice assigned to Molière the first and highest place amongst its comic authors. Nor does there appear to be any reason whatever for impeaching the validity and the soundness of this judgment. Of all the dramatic writers who illustrated the age of Louis XIV., no one attained a higher reputation, or more nearly reached the acmé of perfection in his art. Indeed, Voltaire boldly pronounces him the most eminent comic poet that any age or country has produced; nor is this opinion peculiar to the author of the *Henriade*. When

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Molière. Louis XIV. insisted upon Boileau telling him whom he considered as the most original writer of his time, Boileau answered, Molière. The French comic poet is always the satirist of vice and folly, and of these alone; virtue, with him, is ever sacred. The characters he selected for ridicule were mostly peculiar to the times in which he lived; but he has nevertheless managed to render each as it were the type of a class, and thus to impart to his delineations an universality which must prevent them from ever becoming obsolete. The external manifestations of vice and folly may change with time, and vary according to the fluctuations of fashion, caprice, or accident; yet the essential elements of human character and passion will remain always the same; and Molière penetrated too deeply below the surface not to distinguish the permanent from the accidental, and to catch those generic indications which are at all times equally significant. He possessed comic powers of the very highest order, and wit of the purest kind; his mirth is unalloyed with bitterness, and his pleasantry is always innocent. His comedies in verse, such as the *Misanthrope* and the *Tartuffe*, constitute a specific variety of their class, in which vice is exposed in the style of elegant and polished satire, although with a formal gravity ill suited to our notions of the comic. His verses have all the freedom and fluency of conversation, yet he is said to have passed whole days in fixing upon a proper epithet or a suitable rhyme. In his prose comedies, though there is a profession of ridicule equally pointed and effective, yet there is nothing to offend the most fastidious purity, or to throw contempt on sobriety and virtue. But, with all these high qualities, Molière has also some acknowledged defects. He is not happy in the unravelling of his plots. More attentive to the strong exhibition of character than to the conduct of the intrigue, he seems to be carried away by this natural predilection; and hence the denouement is frequently brought about with too little preparation, and without sufficient attention to probability. The scene is wound up on a sudden, and in a manner which leaves an impression of disappointment, mixed with a conviction that, in unfolding the character, the author has neglected the incidents. In his rhymed comedies he is sometimes not sufficiently interesting, and many of the speeches are by far too long; whilst, in his shorter pieces, intended to serve as interludes or entertainments, the comic often degenerates into the farcical. Upon the whole, however, few writers ever possessed the genuine spirit and attained the true end of comedy so perfectly as Molière. His *Tartuffe* in the grave style, and his *Avare* in the gay, are accounted by his countrymen his two greatest masterpieces. The French Academy, which had declined admitting him as a member on account of his profession, sought to render to his memory the homage which it had considered itself obliged to refuse to his person, and in the year 1778 ordered his bust to be placed in the hall containing the portraits of academicians, with this inscription, proposed by Saurin:

Rien ne manque à sa gloire; il manquait à la nôtre.

And, not content with this, it proposed, as the subject of competition for a prize, an eulogium on Molière. The successful candidate was Chamfort, who evinced much spirit and discrimination in judging and praising the productions of the great dramatist.

Of the works of Molière there have been many editions, but the principal are the following, viz. 1. The edition published by Lagrange and Vinot, Paris, 1682, in eight vols. 12mo; 2. Those of Amsterdam, by Jacques Lejeune, 1675 and 1679, in five vols. 12mo, and that of the same, 1684, in six vols. 12mo; 3. That of Amsterdam, by Wetstein, 1691, in six vols. 12mo; 4. That of Joly, with *Mémoires sur la Vie et les Ouvrages de Molière* by De la Serre, Paris, 1734, in six vols. 4to; 5. A reprint of the pre-

ceding, Paris, 1639, in eight vols. 12mo; 6. That of Amsterdam, 1749, in four vols. 12mo, with figures; 7. That of Bret, with grammatical remarks and observations, and figures, Paris, 1773, in six vols. 8vo; 8. That of Didot the elder, 1792, in six vols. 4to, vellum paper; 9. That of the same, forming part of the Collection of the best Works in the French Language; 10. That of Petitot, accompanied with a life of Molière, a preliminary discourse, and reflections on each piece, Paris, 1813, in six vols. 8vo; 11. That of Auger, in nine vols. 8vo, with engravings from designs by Horace Vernet, a life of Molière, a preliminary discourse, and a commentary. (A.)

MOLINISTS, in ecclesiastical history, a sect in the Roman Catholic church, who follow the doctrine and sentiments of the Jesuit Molina, respecting sufficient and efficacious grace. He taught that the operations of divine grace were entirely consistent with the freedom of human will; and he introduced a new kind of hypothesis to remove the difficulties attending the doctrines of predestination and liberty, and to reconcile the jarring opinions of Augustines, Thomists, Semi-Pelagians, and other polemical divines. He affirmed that the decree of predestination to eternal glory was founded upon a previous knowledge and consideration of the merits of the elect; that the grace, from the operations of which these merits are derived, is not efficacious by its own intrinsic power only, but also by the consent of our own will, and because it is administered in those circumstances in which the Deity, by that branch of his knowledge which is called *scientia media*, foresees that it will be efficacious. The kind of prescience denominated in the schools *scientia media*, is that foreknowledge of future and contingent events which arises from an acquaintance with the nature and faculties of rational beings, the circumstances in which they shall be placed, the objects which shall be presented to them, and the influence which these circumstances and objects must exert on their actions.

MOLINOSISTS, a sect amongst the Roman Catholics who adhere to the doctrine of Molinos. These are the same with those otherwise called *Quietests*, whose chief principle is, that men ought to annihilate themselves in order to be united to God, and afterwards remain in quietness of mind, without being troubled for what shall happen to the body. Molinos, the author of these opinions, was a Spanish priest, and was born in the year 1627. His sixty-eight propositions were examined in 1687, by the pope and the inquisitors, who decreed that his doctrine was false and pernicious, and that his books should be burned. He was obliged to recant his errors publicly in the Dominican church, and was condemned to perpetual imprisonment. He was then sixty years of age, and had been spreading his doctrine twenty-two years before this time. He died in prison in 1692.

MOLISE, a province of the kingdom of Naples, which extends in east longitude from 14. 7. to 15. 5., and in north latitude from 41. 18. to 41. 51., being 1261 square miles in extent. It is divided from the province of Terra di Lavoro by the snowy mountains of Matese, the highest chain of the Apennines, whence the principal rivers, the Biferno, the Trigno, and the Tammaro, have their sources. The province comprises nine cities, sixteen market-towns, and seventy-seven villages, with 206,670 inhabitants, chiefly subsisting by agricultural labour, and having few manufactures and little commerce. Molise produces sufficient corn, oil, and wine for the consumption; and of the first it forms a kind of granary for Campania. Hemp, flax, and silk are also produced, but in small quantities. The capital is the city of Campobasso.

MOLITERNO, a city of Naples, in the province of Principato Citeriore. It is situated between two branches of the river Maglio, on an elevation, with a suburb extending into the valley of Diana. It contains 5176 inhabitants.

Molinists
il
Moliterno.

MOLLUSCA.

Mollusca. THE Molluscous animals to which our attention is to be directed in this article, formed, for a long period, two distinct objects of study. The *naked species* were considered as constituting a particular group, to which the term MOLLUSCA was in a great measure restricted; whilst the *shelly species* attracted a large share of attention, being known as objects of study by the term CONCHOLOGY. Of late years, however, this kind of systematical separation of the naked and shelly species has been supported by few advocates, whilst those who have urged the propriety of their union have not only been numerous, but acknowledged as the intelligent and successful investigators of nature. In consequence of these changes, which have taken place in public opinion by the introduction of more correct notions of the principles of classification, we have in this edition of our work, resolved on incorporating the articles MOLLUSCA and CONCHOLOGY, suppressing the latter term as unnecessary. Indeed, in a physiological point of view, there is no definite boundary between the naked and the shelly species, many of the reputed naked species having shells concealed under their integuments, while in many of the shelly species, the solid plate or shell can only be reached by removing the surrounding soft or fleshy matter. But the propriety of abandoning the old divisions will become sufficiently obvious, when we consider that all the species belong to one group in the INVERTEBRATE class of animals; that the organs of the species have many points of resemblance; and that although differences prevail in the character of the *protecting covering*, the gradations from one condition of the integuments to another, are too minute, in many cases, to admit of precise limits being fixed. We shall therefore consider *shells* as peculiar modifications of the external coverings of certain species, and, in this subordinate character, incorporate the naked and shelly species; having recourse to the integuments, however, in connection with the other organs, in the distribution of the genera and other divisions of the class now denominated MOLLUSCA.

In treating of this extensive division of the invertebrate animals, we shall confine our remarks to a general view of their physiology, taking notice of the peculiarities of their forms, organs, and functions. This will prepare us for a condensed view of the progress of the science, in reference to systematical arrangement, and the illustration of the characters of those divisions or groups into which the species may be distributed, whether for assisting the student in his labours of investigation, or for facilitating the judicious disposition of the established truths of the science. We shall then advert, in the last place, to molluscous animals as objects of utility. The limits of the article will unavoidably restrict us to a very brief exposition of the various subjects connected with this very extensive department of natural history.

CHAP. I.—PHYSIOLOGY.

Physiology Molluscous animals exhibit very remarkable differences, both in their form and in the number and position of their external members. Neither head nor foot can be observed in some species; the principal organs being enclosed in a bag pierced with apertures for the entrance of the food, and egress of the excrementitious matter. In others, with an exterior still remarkably simple, cuticular elongations, termed *Tentacula*, surround the mouth, and a foot, or instrument of motion, may likewise be perceived. This last organ is in some free at one extremity, in others attached to the body

throughout its whole length. In many species there is a *Mollusca* head, not, however, analogous to that member in the vertebral animals, and containing the brain and organs of the senses, but distinguished merely as the anterior extremity of the body, separated from the back by a slight groove, and containing the mouth and *tentacula*.

In many of the animals of this division, the different members of the body are in pairs, and are arranged, in reference to a mesial plane, into right and left. In some, a part only of the organs has respect to a mesial plane, other parts being single, or in unequal numbers. In other species, the organs, which are not in pairs, are arranged round a central axis, and give to the external form a radiated appearance. But these characters are exceedingly variable and uncertain, as indicating the limits of particular tribes; since, in different parts of the same animal, modifications of all these forms may be readily distinguished.

The *skin* of molluscous animals is more simple in its structure, than the same organ in the vertebral animals. The *cuticle* is here very distinct; and, as in other classes, it is thick and coarse where much exposed, but thin and delicate in its texture, where it lines the internal cavities. A *mucous* web may be detected in the cuttle fish and slug, but of great tenuity. The *corium* is destitute of a villous surface; and on its central aspect it is so intimately united to cellular substance, that its fibrous structure can scarcely be distinguished. The *muscular* web may, in general, be readily perceived. Its fibres proceed in various directions, according to the kind of motion to be executed, and extend or corrugate the skin at pleasure.

The appendices of the skin in this class of animals ought to be carefully studied, as they furnish the most obvious marks for distinguishing species, and for constructing divisions in their systematical arrangement. The appendices of the cuticle are few in number, and perhaps ought to be considered as limited to *hairs*. These, in some species, invest the surface regularly and closely, and may be observed on those which live on land, as well as those which reside in water. In some cases the hairs may be considered as united, and forming continuous crusts or ridges. These hairs, as well as the cuticle, are liable to be worn off, and in some places can seldom be perceived, unless in early age.

The most important appendix to the skin, for such it must be considered, appears to be the *shell*. This part is easily preserved, exhibits fine forms and beautiful colours, and has long occupied the attention of the conchologist. The matter of the shell is secreted by the corium, and the form which it assumes is regulated by the body of the animal. It is coeval with the existence of the animal, and appears previous to the exclusion from the egg; nor can it be dispensed with during the continuance of existence. The solid matter of the shell consists of carbonate of lime, united with a small portion of animal matter, resembling coagulated albumen.

The mouth of the shell is extended by the application of fresh layers of the shelly matter to the margin, and its thickness is increased by a coating on the inner surface. These statements are abundantly confirmed by the observations of Reaumur, (*Mémoires de l'Académie des Sciences*, 1709), whose accurate experiments have greatly contributed to the elucidation of conchology. If a hole be made in the shell of a snail, and a piece of skin so glued to the inner margin as to cover the opening, the shelly matter will not ooze out from the broken margin of the fracture, and cover the outside of the skin, but will form a coating on its inner surface,

Mollusca. thus proving it to have exuded from the body of the animal. When a portion of the mouth of the shell of a snail is broken off, and a piece of skin glued to the inner margin, reflected outwardly, and fixed on the body of the shell, the defective part is again supplied, and the matter added to the inner surface of the skin, thus leaving the interposed substance between the new formed portion and the fractured edge. Similar experiments, repeated on a variety of shells, both univalve and bivalve, by different naturalists, leave no room to doubt that shells increase in size by the juxtaposition of shelly matter from the common integuments.

Each calcareous layer is more or less enveloped in the animal matter which we have already stated as being present; so that the different layers of successive growth may, by various processes, be distinctly exhibited. If the shell has been exposed for a short time in the fire, the animal matter will appear charred, and its black colour, contrasted with the white earthy matter, will indicate the arrangement of the different strata; in the same manner as the ivory and enamel of a tooth can be distinguished, when subjected to similar treatment. The same satisfactory results may be obtained by a different process. If the shell be steeped in weak muriatic acid, the earthy matter will be dissolved, and the flakes of albumen will remain as the frame-work of the edifice.

The layers of growth may often be distinguished on the surface of the shell, in the form of striæ or ridges, more or less elevated, but parallel to the margin of the aperture. Other inequalities may likewise be observed on the surface, at right angles to the layers of growth, such as ridges, knobs, and spines. These last derive their origin from the inequalities of the skin on which they have been moulded.

In some univalve shells, the layers of growth parallel to the opening cannot be discerned; when exposed in the fire, there is little darkening of colour; and when dissolved in acids, but a feeble trace of animal matter remains. In the fire, these shells crack in various directions, but exhibit no trace of a scaly structure. By careful management with the file, the shell may be separated into a central layer contiguous to the skin, and a peripheral layer, both similar in structure, though frequently differing in colour. The shells exhibiting such characters have been termed *porcellaneous*, from their dense structure, and the fine polish which their surface presents. The formation of shells of this kind must take place in a different manner from those of the first kind which we have noticed.

If we attend to the form of a young shell belonging to the genus *cypræa* of Linnæus, we may perceive that an addition of shelly matter to the margin of the aperture, in the manner in which it is applied in other shells, would not enlarge the cavity, but completely close the aperture. The increase of the shell, (accompanied with a corresponding increase of its inhabitant), must take place, therefore, either by absorption of the accumulated shelly matter of the mouth, and an elongation in the direction of the greatest curvature of the shell; or the old shell must be thrown off, and a new one produced, suited to the size of the animal. The former supposition has not been entertained, the latter is now generally received by naturalists, though there are a few individuals unwilling to adopt such a view of the matter. The inner coat of such shells appears to be a transudation from the body of the animal, and the outer one to be laid on the surface by the loose reflected lobes of the cloak. In many other shells, portions of matter, more compact than the other parts, may be observed spread on the pillar, and applied to the margin of the mouth by a similar process. Mr. Platt, in support of Reaumur's opinion, that shells are formed by juxtaposition, against the objections of Mr. Poupert, (*Phil. Trans.* vol. liv. p. 43), erroneously considers the different sizes of the *cyprææ* as depending on the thickness of the shell increasing according to age, without admitting a cor-

responding increase of the dimensions of the contained animal, or cavity for its reception.

The shells of the first kind which we have noticed, from being formed of cones or layers applied to the inner edge of the margin, and extending beyond it, have an *imbricated* structure. Those of the second kind, consisting of layers regularly superimposed, have consequently a *laminated* structure; but between the two kinds there are numerous intermediate links, formed by a combination of the two processes.

In some cases, the hard parts of the skin are not entitled to the appellation of shell, but may rather be considered as horn. Such are the coverings of the mandibles of the cuttle fish, the branchial lid of the *aplysia*, and the *operculum* of the welk. The two last appendices, however, though horny in some species, are shelly in others.

The position of the shell, with respect to the constituent layers of the integuments, exhibits very remarkable differences. In some it appears instead of a cuticle, or at least without an external membrane investing it. In general, however, it occurs between the cuticle and the skin; a position which induced Cuvier (*Lec. d'Anat. Comp.* xiv. 11.) to consider it as analogous to the mucous web of the vertebral animals. Its intimate connection with the muscular system of the animal, and the protection which it affords, seem adverse to such a conclusion. In many species the testaceous substance occurs in folds of the corium, or inserted in its substance. In this position it never acquires the solid texture which shells exposed, or covered only by the cuticle, exhibit. Those shells which are thus concealed are in general white; those which are more exposed are frequently coloured. The colouring, however, does not depend on the direct exposure to the light, as some have imagined, for many shells which are destitute of a cuticle are white, while many of those covered with a dense cuticle are finely variegated beneath.

Between the skin and the shell neither vessels nor nerves have been traced; and the manner in which the latter is formed, forbids us to expect their existence. Yet the shell cannot be considered as dead matter, so long as it remains in connection with the living animal. In those animals in which the shell is external, there are muscles which connect the animal with its internal surface, and the bond of union being a substance soluble in water, the muscle can be detached by maceration. The analogy between shell and bone is here obvious, although in the one case the connection between the muscle and the bone is permanent, in the other, between the muscle and shell, temporary, or frequently changed during the life of the animal. But the vitality of the shell, if I may use the expression, is demonstrated, from the changes which it undergoes when detached from the animal: the plates of animal matter harden: the epidermis dries, cracks, and falls off; and in many cases the colours fade or disappear. We confess ourselves unable to point out the means employed by the animal to prevent these changes from taking place, by any process similar to circulation. The difficulty, however, is felt in contemplating the functions of hairs, nails, and feathers, in vertebrated animals.

When the shelly covering consists of two or more pieces, they are joined together, as the articulated bones in the higher classes of animals, by ligaments. These, in some cases, are of great thickness and strength, and, in consequence of their elasticity, assist in the motion of the different parts.

In the molluscous animals the skin secretes a viscous, adhesive substance, differing according to the medium in which the animal resides, but in all cases calculated to resist its influence. It is probably owing to the lubricating agency of this secretion, that both the cuticle and shell are preserved from decomposition. The skin likewise secretes the colouring matter by which the shells are variegated.

Mollusca. The glands from which it proceeds vary much in different individuals, and even in the same individual in different periods of growth.

The characters furnished by the skin and its appendices are extensively employed in the systematical arrangement of molluscous animals. Nearly all those characters which distinguish the species, and many of those on which genera are established, are derived from the form of the shell, the *tentacula*, or the colour. This last character, however, is one on which little dependence should be placed.

Muscular system.

There is nothing peculiar in the **MUSCULAR SYSTEM** of this class of animals. Where the muscles are inserted in the skin, as is usually the case, that organ is in some cases strengthened by condensed cellular substance, and even acquires a leathery density.

Molluscous animals preserve themselves in a state of *rest*, chiefly by suction and cementation. The organ which acts as a sucker, is in some cases simple, soft, and muscular, as the foot of the snail, while in others it is compound, and strengthened internally by hard parts, as in the arms of the cuttle fish. The force with which some animals adhere is very considerable, and is strikingly displayed, for example, when we attempt to detach a limpet from the rock.

The *rest*, which is maintained by cementation, in some cases depends on a glairy secretion, which, glues the body of the animal to the substance to which it is disposed to be attached. By such an expedient, the shells of snails adhere to rocks, stones, and plants. It is probable that the bivalve shells of the genus *Cyclas*, which readily adhere to the side of a glass, secure their temporary attachment by means of their glutinous cuticle. In other animals threads are produced, termed a *byssus*, from particular glands, and while one extremity is glued to the rock, the other remains in connection with the animal. But there is an attachment more durable than any of these, which takes place in some shells, they being cemented to rocks or stones by calcareous matter, and retained in the same position during the whole term of their existence.

The locomotive powers of the mollusca are confined to creeping and swimming. The former action is performed by alternate contraction and relaxation of the foot, or muscular expansion, which serves as a sucker, and is analogous to the motion of serpents. The motion of swimming is executed either by the serpentine undulations of the foot and the body, or by the action of tentacula, or expanded portions of the integuments. Many species are aided in swimming, by being able to vary the specific gravity of their body at pleasure, and either rise or sink in the water as circumstances may require. In some, as the *Janthina*, there is a cellular organ peculiarly destined for this purpose, which may be regarded as in some measure analogous to the air-bladder of fishes. In all these exertions the progress of molluscous animals is proverbially slow. Some bivalve shells have the power of *leaping* or shifting their position by a sudden jerk, produced by shutting the valves rapidly. This is strikingly displayed in the common Scallop, and is less perfectly exhibited in the river muscles. In a few instances, especially among the slugs, a thread is formed of the viscous secretion of the skin, by which the animal is enabled to suspend itself in the air from the branches of trees like a spider.

Although the progressive motions of molluscous animals are comparatively slow, the other muscular actions are executed with ordinary rapidity. The irritability of some parts, as the tentacula and branchiæ, is so great, that the protecting movements are executed almost instantaneously, and the organs are contracted or withdrawn into the body. But these rapid exertions are only called forth in the moments of danger.

The characters furnished by the muscular system, are of great value in the discrimination of species, and in the con-

struction of genera and higher divisions. They are intimately connected with the habits of the animal, and merit the attentive examination of the philosophical naturalist.

In the molluscous animals the **NERVOUS SYSTEM** is less complicated in its structure than in the higher classes, and the brain is not restricted in its position to the head. The whole nervous system appears in the form of ganglia and filaments. The principal ganglion, or the one to which the term *brain* is usually applied, is seated above the gullet or entrance to the stomach. It sends out nerves to the parts about the mouth, the tentacula, and the eyes. It may be considered as analogous to the cerebrum of the vertebral animals. From this ganglion proceed two filaments, one on each side, which in their descent inclose the gullet, and unite underneath to form a second ganglion. From this last, which has been compared to the cerebellum, numerous filaments are likewise distributed to the parts around the mouth, and to the other regions of the body. These filaments in some cases again unite, and form subordinate ganglia. In many cases the brain and ganglia are of a reddish colour, and granulated structure, while the nerves which issue from them are white and uniform, as in the genus *Aplysia*. The covering of the first ganglion, which is analogous to the *dura mater*, does not adhere to it closely, but leaves a space filled with loose cellular matter. The tunics of the nerves are equally detached; and as they can be inflated or injected readily, some have been led to suppose that the nerves were hollow, and others, that the tunics were the vessels of the lymphatic system.

The organs of perception common to the higher classes of animals, do not all exist in an obvious manner amongst the mollusca. The *touch*, that universal sense, is here displayed in many cases with great delicacy; and the tentacula, and the other cuticular elongations which we have already referred to, contribute to augment its resources. The sense of *sight* is by no means universally enjoyed by the inhabitants of this class. In a few species, the eye is constructed on the plan of the same organ in the vertebral animals. In general, however, it appears only as a black point, the peculiar functions of which can only be inferred from analogy. In many species there is no trace of an eye, consequently they cannot possess that varied information which the others derive from that organ. Where eyes exist in this class, they are uniformly two in number. In one tribe only, namely the cuttle-fish, the rudiments of the organs of *hearing* have been detected. The organs adapted to *smelling* cannot be exhibited, but the existence of the sense is demonstrated by the facility with which molluscous animals discover suitable food, when placed within their reach. The sense of *taste* appears to exist, but it is difficult to point out the particular parts of the mouth fitted for its residence. As, however, particular articles of food are selected in preference to others, it may be concluded from analogy that taste regulates the choice.

In the classification of the mollusca, the characters furnished by the nervous system, from the difficulty of their detection and exhibition, have never come into use. But those furnished by the organs of preception are highly prized. Of these, the eye is the most obvious and constant. It varies in position in different species; but, among individuals of the same species its characters are constant.

In the cutaneous, muscular, and nervous systems, traces of a general plan may be observed, according to which they have been constructed in the different tribes. In the organs which remain to be considered, there is less uniformity of structure, each family almost, being constructed according to a model of its own.

The time when molluscous animals feed has not been carefully attended to. Those which live in the water are beyond the reach of accurate observation. Those that reside on land usually shun the light, and creep forth in the

Mollusca. evenings to commit their depredations. During warm, dry weather, they stir not from their holes.

The animals under consideration, feed equally on the products of the vegetable and animal kingdom. Those which are *phytivor* appear to prefer living vegetables, and refuse to eat those which are dried. We are not aware that putrid vegetable matter is consumed by them, although many of the snails and slugs are found under putrid leaves and decayed wood. In these places there is shelter from the sun, together with dampness, so that it is difficult to determine, whether they sojourn in an agreeable dwelling, or a well-stored larder. Those mollusca which are *carnivorous*, prey on minute animals in a living state, and many of them greedily attack putrid matter.

The means employed to bring the food within the reach of the organs of deglutition, are exceedingly interesting, both on account of their variety and success. Some are provided with *tentacula* for securing their prey, and conveying it to their mouth, as the cuttle-fish; others protrude a lengthened proboscis, or an extended lip or tongue, as the limpet, and thus bring their food into the mouth. By many, however, which are fixed to the same spot during the continuance of existence, or only capable of very limited locomotive power, successful efforts are made to excite currents in the water, whereby fresh portions of it are brought in contact with the mouth, and its animal or vegetable contents separated. Where part only of any kind of food is taken into the mouth at once, the lips are possessed of sufficient firmness to cut off the requisite portions, or there are corneous mandibles to perform the office.

In the mouth, there is scarcely any process performed analogous to that of mastication, in the higher orders of animals. When the food is in the mouth, or entering into the gullet, it is mixed with saliva, as in the more perfect animals. The *salivary glands* in which it is secreted, are in general of considerable size, divided into lobes, and, in some cases, separated into distinct masses. In many species the existence of a gullet is doubtful, as the food seems to enter the stomach immediately; while, in others, there is a portion of the intestinal canal which has some claim to the denomination.

The stomach, in many instances, is membranaceous, and can scarcely be distinguished from the remaining portion of the intestinal canal. In some cases, however, it is strong and muscular like the gizzard of a bird, and even fortified with corneous knobs for the reduction of hard substances. In some species, the stomach opens laterally into the pyloric, and, in a few instances, possesses a spiral cœcum attached to it.

The *liver* is usually of very large dimensions, and seated close to the stomach, which it, in many cases envelopes. It is divided into many lobes, and receives numerous blood-vessels. There is, however, nothing analogous to the *vena portarum* of quadrupeds. The *bile* is poured, in some, into the stomach, and, in others, into the pyloric extremity of the intestine by different openings. There is no gall-bladder.

There is no division of the canal into small and large intestines, as in the higher classes; or rather, among the mollusca, the relative size of the different parts is reversed. Here the pyloric extremity is usually the largest, while the anal is more slender. The intestine, as in fishes, is short in proportion to the length of the body, and in its course, is subject to few turns. The anus is, in some, placed on one side of the body; in others it is terminal, while in a few it opens on the back.

The digestive system is thus more simple in its structure than in the higher classes. It possesses neither pancreas, spleen, nor mesentery. And, we may add, that the calls of hunger are often at distant intervals, and the power of abstinence very great.

The characters furnished by the digestive system are extensively used in the inferior divisions of molluscan animals. The form of the lips, the position of the mouth and anus, and the structure of the stomach, deserve to be attentively considered, as indicating the habits of the species.

CIRCULATING SYSTEM.—The process by which the food is converted into chyme, has not been satisfactorily traced, nor has the existence of the lacteals for the absorption of the chyme been demonstrated. In this class of animals the veins seem to perform the offices both of lacteals and lymphatics. The blood is white, or rather of a bluish colour. Its mechanical and chemical constitution yet remains to be investigated.

The circulating system of molluscan animals, exhibits very remarkable differences in the different classes. In all of them, however, there is a systemic ventricle; but the other parts of the heart are not of constant occurrence.

The circulating system furnishes few characters which can be employed in systematical arrangements. The structure of the systemic and pulmonary vessels does not appear to be co-ordinate with any particular plan of external configuration and manner, as we see in the case of the pteropoda and gasteropoda. In these, the organs of circulation are very much alike, while the external forms exhibit very obvious differences.

The molluscan animals which respire by means of *lungs* are few in number, and form a very natural tribe, which Cuvier has termed *gasteropodes pulmones*. In them the respiratory organ is simple, consisting of a single cavity, on the walls of which the extremities of the pulmonary artery are spread. This cavity communicates externally by an aperture which the animal can open or shut at pleasure.

The mollusca which breathe by means of *gills*, exhibit very remarkable differences, in their number, structure, and position. In some cases, there is a single cavity communicating by an aperture, through which the water enters. The walls of this cavity exhibit an uneven surface, disposed in ridges, which are the gills, and on which the pulmonary artery is expanded. This structure exhibits itself in the *Gasteropoda pectini-branchia*. In many cases the gills, though seated in a cavity, like the former, and equally exposed to the contact of the surrounding element, are two in number, one on each side, as in the *Cephalopoda*. In the *Bivalvia*, they are four in number, two on each side like leaves, and extend the whole length of the body. In these, the water is admitted at the pleasure of the animal.

The gills of other mollusca are seated externally, and consist either of aborescent productions, or simple cuticular elongations, within which the pulmonary artery terminates. In some of these, as the *Pteropoda*, the branchial surface is constantly exposed to the action of the surrounding water; whilst in others, the cuticular expansions, which are analogous to gills, are retractile at the will of the animal. In several examples, these cuticular elongations, which execute the functions of respiration, are covered with moveable cilia, well calculated to excite currents in the water, thus renewing the portions applied to the surface.

By means of the characters furnished by the circulating and respiratory systems, the molluscan animals may be divided into several distinct classes. But as we shall employ these characters in the construction of the different divisions to be employed, it is unnecessary, in this place, to enter into their details.

PECULIAR SECRETIONS.—The molluscan animals are considered as destitute of organs for the production of urine, but they possess various organs for the secretion of peculiar fluids or solids, some of which are useful in the arts.

The coloured fluid, which is secreted by the *Cephalopoda* and some of the aquatic *gasteropoda*, appears to consist chiefly of a peculiar mucus, united to a peculiar pigment. The animals which furnish this secretion, eject it when in

Mollusca. danger or irritated, and thus envelope themselves in a dark cloud, and elude the pursuit of their foes. A milky secretion is poured forth over the surface of the skin of some slugs when irritated. Other coloured secretions may likewise be detected in the mollusca, to which we shall afterwards advert. The threadlike secretions, termed a *byssus*, with which some molluscous animals, especially among the *Conchifera*, fix themselves to other bodies, appear to be of an albuminous nature. A few species in this division have the power of secreting a *luminous* fluid. Its nature, and the organs in which it is elaborated, have not been investigated. It is probable that some animals, as those which have the faculty of raising or lowering themselves in the water, have likewise the power of secreting *air* into those organs which contribute to their buoyancy.

Morbid secretions likewise occur amongst the animals of this division, chiefly, however, amongst the *Conchifera*. The most important of these are *pearls*, so much prized as ornaments of dress.

The organs of generation, some of which will be noticed afterwards in detail, furnish many important characters for classification. The external openings are those which are detected with the greatest facility, but the structure of the internal organs exhibits more varied and discriminating marks.

Condition. **CONDITION OF THE MOLLUSCA.**—Molluscous animals, in reference to their condition, are divided, according to the situation in which they reside, into three groups, which may be termed terrestrial, fluviatile, and marine. Those that inhabit the land belong exclusively to the gasteropoda. Among these, some prefer open pastures, others the rubbish of old walls, while not a few reside in woods or among dead leaves and putrid plants. All the animals of this group respire by means of a pulmonary cavity.

The fluviatile mollusca, or such as reside in fresh waters, include not only many gasteropodous genera, but likewise a few belonging to the *Conchifera*. Amongst these, some breathe air by means of a pulmonary cavity, and come to the surface to respire. Such species frequent the more shallow ponds and lakes. Others, respiring by means of gills, are less dependent on the shallowness of the water, and consequently reside in different depths.

The marine mollusca include genera of all the classes. Some burrow in the sand, or adhere to the rocks which are left dry by the receding tide. These are termed *littoral* species. Others, however, which have been denominated *pelagic*, reside in the deep, and are seldom obtained but by dredging, or when thrown ashore during storms.

The effect of temperature in regulating the distribution of molluscous animals, has not been investigated with any degree of care or success. Over the terrestrial and fluviatile species, it probably exercises a very powerful control, greatly limiting their geographical range. In proof of this, it may be stated, that the south of France possesses several species not to be found in England, whilst in England, there are a few which have not been detected in Scotland. But, among the marine mollusca, the influence of climate is not felt in the same degree. Living in an element, the bulk and motions of which guard it equally from the extremes of heat or cold, these animals, like the sea-weeds, have a very extensive latitudinal and longitudinal range. Thus, some are common to Greenland and the Mediterranean, others to Britain and the West Indies. The mollusca of the tropical seas, however, differ widely as a whole from those of the temperate regions. Some of the forms appear to be peculiar to warm regions, and, in general, the intensity of colour decreases as we approach the poles. But as there have been few cultivators of this branch of science, the geographical distribution of the species has been but imperfectly explored. Few parts of either England or Scotland have been surveyed by the eye of the helminthologist, so that many

species, the range of which is considered as limited, may soon be found to be extensive.

If the observations are few and imperfect, which have been made on the influence of temperature, in regulating the physical distribution of mollusca, we are still in greater ignorance with regard to the power of habit. In the *flötz* rocks, the relics of marine and fluviatile mollusca are found mixed in the same bed. This circumstance gave rise to the inquiry, how far the mollusca of fresh water can be habituated to sea-water, and *vice versa*. In the account of the proceedings of the National Institute of France, for the year 1816, it is stated, that M. Beuchant, professor at Marseilles, has directed his attention to this subject. He found, that all these animals die immediately, if we suddenly change their place of abode; but that, if we gradually increase the proportion of salt in the water for the one set, and diminish it for the other set, we can, in general, accustom them to live in a kind of water which is not natural to them. He found, however, some species which resisted these attempts, and which could not bear any alteration in the quality of the water in which they reside. Before much confidence can be placed in the accuracy of these results, it would be desirable that the experiments were repeated and varied by other observers. There are, indeed, many sources of error to be guarded against. When we change animals from fresh to salt water, or from salt water to fresh, we must necessarily derange their motions, by compelling them to reside in a medium of a different degree of density from the one in which they have been accustomed to dwell, and to which the arrangement of the different parts of the body is adapted. By such a change of place, it would be difficult for those which breathe air to come to the surface, and descend again in their new situation. In those with gills, the application of a new kind of fluid to the surface of such delicate organs, would considerably influence the function of respiration. The change of situation would likewise be accompanied by a corresponding change of food, and consequently, not merely the organs of locomotion and respiration, but likewise those of digestion, would suffer a derangement in their operations. We know that the power of *suffering* in the animals of this class is very great, and that they survive, though sadly mutilated. Some of the snails will live in a quiescent state for years, without food, and almost without air. Unless, therefore, the animals subjected to these experiments of a change of situation, have been observed to thrive on the food which it spontaneously yields, to execute their accustomed motions, and above all, to propagate their kind, we shall be disposed to conclude, that patient suffering has been mistaken for health and vivaciousness for the power of accommodation.

The influence of the *seasons*, in regulating the motions and habits of molluscous animals, has been but little attended to. Those which live in the water, avoid the effects of low temperature, on the approach of winter, by retiring to the deeper parts of the lakes or rivers in which they reside. This migration, however, does not, in many cases, furnish the requisite security, so that they betake themselves to burrowing in the mud in which they repose until increasing warmth invites them to return to the open water.

Among the naked terrestrial mollusca, it may be observed, that they burrow in holes of the earth, under the roots of trees or among moss, and there screen themselves from sudden changes of temperature, and appear to spend the winter in a state of torpidity.

The different kinds of shelly mollusca which inhabit the land, such as those belonging to the genera *Helix*, *Bulimus*, and *Pupa*, not only retire to crevices of rocks and other places, for safety in the winter season, but they form an operculum or lid for the mouth of the shell, calculated to exclude the access of the air, and by the intervention of which they likewise adhere to the wall of their dwelling. A

Mollusca. rise of temperature, however, especially if accompanied by moisture, excites their revival and motion, and the lid becomes detached. If we bring, for example, the *Helix nemoralis*, from its cold abode, and in an apparently torpid state, with the mouth of its shell closed by the lid and adhering to a stone, into a warm apartment, it will speedily revive, especially if it be moistened with a little water, burst open the lid and begin to crawl. If the animal be again exposed to a low temperature, it again secretes materials for a new lid, and speedily returns to its slumbers or inactivity. The first formed opercula, in these animals, always contain a considerable proportion of carbonate of lime, a material which is found in smaller quantity in those of after formation. If the animal has revived frequently during the winter, the last formed opercula will be observed to consist chiefly of animal matter, and to be very thin. The first formed winter lid of the *Helix Pomatia* is of the consistence of card-paper.

All the land shelly mollusca appear to have the power of passing into a state of *quiescence* resembling torpidity, at pleasure, and independent of low temperature. Thus, even in midsummer, if we place in a box specimens of the *Helix hortensis*, *nemoralis* aut *arborum*, without food, in a day or two they form for themselves a thin operculum, become attached to the side of the box, and assume a dormant condition. In this state of apparent torpidity they may be kept for several years. No ordinary change of temperature produces any effect upon them, but they speedily revive if moistened or plunged in water. Even in their natural haunts, they are often found in this dormant state, during the summer season, especially when there is a continued drought. Thus the *Helix nemoralis* may frequently be observed several feet from the ground, and attached to the stem or leaves of plants, with the mouth of the shell closed.

But it is not drought which influences these terrestrial shelly mollusca to assume this quiescent state. The *Succinea putris*, a species in ordinary cases delighting in moisture, may readily be observed during summer in a dormant state, high on the leaves of the Water Flag, having retired from the moisture below. In the same manner, and from causes equally obscure, some of the marine shelly mollusca, as the Limpet, Periwinkle, and Trochus, may be observed in a quiescent state on the rocks, above the reach of the tide. A shower, however, in general excites the *Succinea*, as well as the Limpets and Periwinkles, to motion.

CHAP. II.—PROGRESS OF THE SCIENCE.

Naturalists have pursued a variety of methods in their examination of this important branch of Zoology, and have proposed systems of arrangement founded on very different principles, and marking different epochs in the science. In the methodical distribution observed by some, the form of the shelly covering has been exclusively attended to, while the organization of the animal itself has been overlooked, or even disregarded. A few have made the habits of the animal, the groundwork of their system. Others have passed over the characters exhibited by the forms and structure of the shell, and have confined their attention exclusively to the form and structure of the contained animal. Lastly, there have been a few, who, embracing all the circumstances connected with the shell, the animal, and its habits, have constructed systems at once natural and convenient. In the following sections we propose to consider these four classes into which the cultivators of this department of science may be distributed.

SECT. I.—Systems constructed from circumstances connected with the characters of the Shell.

The arrangement of the testaceous mollusca, according
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to the different forms of the shell, is unquestionably the most obvious and the most ancient method. It was first employed by Aristotle, the father of natural history, and even in the present day its admirers are warm in its praise. It is with great propriety termed the *artificial method*, because the characters employed have but a remote relation to the more important functions of the animal. This eminent philosopher had the merit of forming the great divisions of *univalves* and *bivalves*. He likewise separated the turbinated univalves from such as have but an imperfect spire, and formed many genera, or rather families, still retaining the names which he imposed.

The progress of the study of the shelly mollusca (the naked kinds being in a great measure neglected,) made very little progress for many ages after Aristotle had published his method of arrangement. Indeed, the first work of this sort which claims attention, is the *Dictionarium Ostracologicum* of Major, which was published in 1675. To him we are indebted for the threefold division of shells into *univalves*, *bivalves*, and *multivalves*, and for an explanation of the terms then employed by conchologists.

In the same career, but with more brilliant success, *Langius* followed, and, in 1722, published his *Methodus Nova Testacea Marina in suas Classes, Genera et Species distribuendi*. The following character is given of this work by the intelligent and industrious authors of the *Historical Account of Testaceological Writers*. (*Linn. Trans.* vol. vii. p. 156.) "After having noticed a multitude of mere describers, we now come to an author who is not undeserving of the title of a scientific one, and whose system, so far as marine *testacea* are concerned, (and of these alone he treats) certainly glances at the great clue to simplicity, which was afterwards so successfully and admirably seized by the great reformer of natural history in general." But *Langius* deserves more praise than is here bestowed upon him. Before his system appeared, the characters of the genera depended principally on the *outline*, and were of uncertain application. He remedied the defect, by directing the attention of conchologists to the form of the mouth in univalves, and to the structure of the hinge in bivalves. Among the former, he constituted subdivisions of those *ore superius aperto*, *ore superius in canaliculum abeunte*, and *ore superius clauso*. Amongst the latter, the circumstance did not escape him, that some of these shells are *equivalve*, others *inequivalve*; some *equilateral*, others *inequilateral*. Hence he may be considered as the founder of the inferior divisions of the artificial method, and as having furnished, to modern conchologists, many useful hints, of which they have availed themselves, without, however, acknowledging their origin.

Another important improvement was effected by *Breyneus* in his *Dissertatio Physica de Polythalamis*, 1732, in 4to. This consisted in separating from the ordinary univalves, such shells as possess a cavity divided by partitions into several compartments, and in forming them into a division, which he termed *Polythalamium*. These shells are now called Multilocular.

The system of *Tournefort*, which was published by *Gualtieri*, in his *Index Testarum Conchyliorum quæ adservantur in Museo Nicolai Gualtieri, Philosophi et Medici, Florentini*, 1742, well deserves an attentive perusal. In his observations on the bivalves, now denominated the acephalous mollusca, he drew the attention of conchologists to an important character, and one of easy application, having observed that, in some genera, the valves do not close or unite all round, but that, at certain places, the shell remains in part open. Such shells, in modern language, are said to *gape*.

The system of the celebrated *Linnæus*, which ought now to be mentioned, is too well known in this country to deserve particular notice. In many of the other departments

Mollusca. of Zoology he effected the most important alterations; but his attempts to reform the science of conchology, were far from being equally successful. To the subject he never was much attached, nor does he appear to have availed himself sufficiently of the labours of those authors whom we have mentioned, and of others who preceded him. The primary divisions which he employed, were those which Major had established, and his genera, with a few exceptions, were those in common use. His merit as a conchologist rests entirely on the accurately defined terms, the concise specific characters, and the convenient trivial names which he employed and introduced. The particular consideration of the Linnæan genera, and the subsequent changes which have been introduced into them, will form the subject of a separate section.

For some time after the publication of the *Systema Naturæ*, the illustrious Swede enjoyed a very dangerous reputation. All his arrangements were regarded as of such high authority, that it was considered as impious to attempt to introduce any change; so that conchology, and along with it the study of the mollusca, according to the artificial method, remained a long time stationary. At last in France, a country which refused to submit to the fetters of the Linnæan school, several new systems were proposed, which had for their object the restoration of those well-founded genera, which Linnæus, in his too great desire to simplify, had suppressed, and the accommodation of the divisions of the science to those new relations which a more extensive knowledge of species had discovered. In this number Bosc stands eminently conspicuous. In his work entitled *Histoire Naturelle des Coquilles, des Vers et des Crustacés*, and in the conchological articles of the *Dictionnaire d'Histoire Naturelle*, he has favoured the world with a detail of his system, the outline of which we shall here present to our readers:

I. COQUILLES MULTIVALVES.

1. Les unes n'ont point de charnière.
Oscabron, Anatif, Balanite.
2. Les autres en ont une.
Pholade, Taret, Fistulane, Anomie, Calceole.

II. COQUILLES BIVALVES.

i. *Equivalves*.

1. A charnière sans dents.
Pinna, Modiole, Moule, Anodonte.
2. A charnière garnie des dents.
 - A. A une dent.
Mulette, Crassalette, Paphie, Mactre.
 - B. A deux dents.
 - a. Simple. Trigonie, Tridacne, Hyppope, Cardite, Lutraire, Petricole, Venericarde, Solen, Capse, Sanguinaire.
 - b. Avec des surnuméraires. Isocarde, Donace, Cyclade, Telline, Venus.
 - C. A quatre dents.
Bucarde, Mérétrice, Lucine.
 - D. A beaucoup de dents.
Nucule, Petoncle, Arche, Cucullee.

ii. *Inequivalves*.

1. A charnière sans dents.
Acarde, Radiolite, Vulselle, Marteau, Huitre, Avicule, Peigne, Lime, Houlette, Cranie, Hyale, Linqule.
2. A une dent.
Came, Corbule.
3. A deux dents.
Spondyle, Plicatule, Placune, Pandore, Terebratule, Calceole.
4. A plusieurs dents.
Perue.

III. COQUILLES UNIVALVES.

i. *Uniloculaires*.

1. Sans spirale.
 - A. En Calotte.
Patelle, Oscane.
 - B. En Tube.
Vermiculaire, Silicaire, Arrosoir.
2. En spirale.
 - A. L'ouverture entière et sans canal à sa base.
Carinaire, Halotide, Sigaret, Stomate, Argonaute, Concholepas, Nerite, Natic, Helicine, Helice, Volvaire, Bulle, Jacinthe, Turritelle, Cyclostome, Bulime, Sabot, Toupie.
 - B. L'ouverture échancrée et canaliculée à sa base.
Cérîte, Pyrûle, Rocher, Rostelaire, Strombe, Buccin, Casque, Vis, Pourpre, Volute, Ovule, Tarrière, Porcelaine, Cone.

ii. *Multiloculaires*.

Nautilite, Orbulite, Ammonite, Planulite, Camérine, Rotulite, Turritite, Baculite, Spirule, Orthocère, Hippurite, Belemnite.

In this system which we have exhibited, the arrangement is more methodical, and the genera are more definite, than in the Linnæan system. It unquestionably holds the first rank in the modern artificial methods.

There is a class of writers whose labours deserve some Microscopic notice in this place. We allude to those who have devoted their attention to the very minute shells, so common among the sand on every sea-coast. These are too small to be examined by the naked eye, and from the instrument employed in their investigation, they are usually termed *Microscopic Shells*. Plancus, in his work, *De Conchis Ariminensibus minus notis*, published in 1739, may be considered as the first who drew the attention of conchologists to these nearly invisible objects. J. F. Hoffman, in his *Dissertationcula de Cornu Ammonis nativo Littoris Bergensis in Norvegia*, published in the *Transactions of the Electoral Academy of Mentz*, 1757, and in his essay *de Tubulis Vermicularibus Cornu Ammonis referentibus*, *ibid.* 1761, made us acquainted with various species of minute nautili produced on the northern shores. Nor did those discoveries fail to excite interest in this country. Boys and Walker devoted their attention to the subject, and gave to the world the result of their labours, in a thin quarto, entitled, *Testacea Minuta rariora nuperrime detecta in arena littoris Sandvicensis*, London, 1784. Other observers, equally ardent and successful, have increased our knowledge of the forms of these minute bodies, particularly Soldani, who, in his *Testaceographia ac Zoophytographia parva et microscopica*, 1789 and 1795, exhibited many figures of the minute shells of Portoferrara, &c. Mr. Adams likewise described the minute species which he observed on the coast of Pembroke-shire, in the third and fifth volumes of the *Transactions of the Linnæan Society of London*, and other species of British growth have been investigated by the author of *Testacea Britannica*. We shall close this list with noticing the *Testacea Microscopica aliæque minuta ex generibus Argonauta et Nautilus ad Naturam Picta et Descripta*, Vienna, 1798. It is the joint production of L. A. Fichel and J. P. C. A. Moll, and merits an attentive perusal.

We are aware that such microscopic investigations are regarded by some conchologists as useless, so that the minute species are excluded from their systems. But it is surely a strange method of proceeding in natural history, to judge of the merits or importance of species from their size. It is true that we are still ignorant of the inhabitants of those shells, and may long continue to be so; but our present knowledge of these shells has enabled us to fill up many blanks, to perceive several new relations, and even to draw some important conclusions.

Mollusca. That this sort of inquiry has in many instances been injudiciously conducted, all who are acquainted with the subject must admit. Due care has not been taken to distinguish these minute testacea from the fry of the larger shells, so that the number of species has been very injudiciously multiplied. These remarks apply to several figures of Walker, and to a still greater number of those of Adams.

SECT. II.—*Systems constructed from Circumstances connected with the Habits of the Animal.*

Systems founded on the habits of the animal. The authors of the preceding class have laboured to bring to perfection the artificial system of conchology, and have formed their arbitrary characters, independent of the habits of life of the contained animal. But the naturalists whom we have now to consider, have traced these animals to their lurking places, and arranged them according to the situation in which they reside, instead of the forms which they exhibit.

Lister. At the head of this class of conchologists, Dr. Martin Lister stands pre-eminently conspicuous. His great work, entitled *Historia sive Synopsis Methodica Conchyliorum*, was begun in 1685, and completed in 1692. It will long remain a monument of the extensive information and unwearied diligence of its author. The following synoptical view of the work will enable our readers to comprehend its plan; the original should be consulted with care.

Lib. i. De Cochleis terrestribus.

Pars 1. De Buccinis terrestribus.

Pars 2. Cochleæ nudæ terrestres Limaces quibusdam dictæ.

Lib. ii. De Turbinibus et bivalvibus aquæ dulcis.

Pars 1. De Turbinibus.

Pars 2. De Testaceis bivalvibus fluviatilibus.

Lib. iii. De Testaceis bivalvibus marinis.

Pars 1. De Testaceis bivalvibus, imparibus testis.

Pars 2. De Testaceis bivalvibus, paribus testis.

Pars 3. De Testaceis multivalvibus.

Lib. iv. De Buccinis marinis, quibus etiam vermiculi, dentalia et patellæ numerantur.

Sibbald. The plan followed by Sir Robert Sibbald in his *Scotia Illustrata* is somewhat different from that of Lister. He divides the Testacea into two classes, land and water shells, and the latter class he subdivides into fluviatile and marine. His inferior divisions are destitute of precision, and the number of species referred to limited.

D'Argenville. The system of D'Argenville, which was so much esteemed and so long followed in France, is essentially the same with that of Lister in the higher divisions. The plan is indeed so simple, and in appearance so natural, that it has met with many admirers. It has even been useful in encouraging naturalists to study particular departments of the science, when they were prevented by their situation from devoting their attention to the whole. It is probably to this circumstance that we are indebted to Schröter for his observations on the land shells in the neighbourhood of Thangelstadt, and on the river shells of Thuringia.

The preceding arrangements, formed according to the situations in which the animals reside, and not according to their external coverings, may be considered as the first attempts at a natural method in conchology. They serve as an introduction to a new class of authors, whose views may be considered as of a higher order, and to whose labours we shall devote our attention in the following section.

Systems. SECT. III.—*Systems constructed from Circumstances connected with the Form and Structure of the contained Animal.*

The first attempt of any consequence to arrange testaceous animals according to the soft parts of their bodies, was

made by Adanson, in his *Histoire Naturelle du Sénégal*, Mollusca. published at Paris in 1757. In this system, the ancient classes of Univalves, Bivalves, and Multivalves, are employed under the titles *les Limaçons*, *les Conques*, and *les Conques Multivalves*. Adanson.

CLASSE I. Les Limaçons.

Sect. I. Les Limaçons Univalves.

Fam. 1. Les limaçons univalves qui n'ont ni yeux ni cornes.

Fam. 2. Les limaçons univalves qui ont deux cornes, et les yeux placés à leur racine et sur leur côte interne.

Fam. 3. Les limaçons univalves qui ont quatre cornes, dont les deux extérieurs portent les yeux sur le sommet.

Fam. 4. Les limaçons univalves, qui ont deux cornes et les yeux placés à leur racine, et sur le côté externe, ou pas derrière.

Fam. 5. Les limaçons univalves qui ont deux cornes et les yeux posés un peu au dessus de leur racine et sur leur côté externe.

Sect. II. Les Limaçons Operculés.

Fam. 1. Limaçons operculés qui ont deux cornes, avec un renflement, et qui portent les yeux ordinairement au dessus de leur racine, et à leur côté externe.

Fam. 2. Limaçons operculés qui ont deux cornes sans renflement, et les yeux placés à leur racine, et sur leur côté externe.

Fam. 3. Limaçons operculés qui ont quatre cornes, dont les deux extérieurs portent les yeux sur leur sommet.

CLASSE II. Les Conques Bivalves.

Fam. 1. Les conques bivalves qui ont les deux lobes du manteau séparés dans tout leur contour.

Fam. 2. Les conques bivalves dont les deux lobes du manteau forment trois ouvertures sans aucun tuyau.

Fam. 3. Les conques bivalves dont les deux lobes du manteau forment trois ouvertures, dont deux prennent la figure d'un tuyau assez long.

The presence or absence of an *operculum* or lid, gives rise, in this system, to a division of the univalves into two sections, and the families are established from circumstances connected with the number of the tentacula, and the number and position of the eyes. The families amongst the bivalves are arranged according to the structure of their cloak or external covering. In the class of multivalves, which we have omitted in the table, the characters are taken from the form and structure of the shell.

The work of Geoffroy, entitled, *Traité Sommaire des Coquilles tant fluviatiles que terrestres, qui se trouvent aux environs de Paris*, 1767, is constructed upon the principles of Adanson. Here, however, the objects were not sufficiently numerous to admit of all the subdivisions of that author, but he has made the form of the animal subservient to the construction of generic characters.

After these attempts to classify the animals which inhabit shells had been made in France, the celebrated zoologist of Denmark, O. F. Müller, turned his attention to the same subject. In the *Zoologia Danica*, which contains his digested views of the subject, he employs, in the construction of his genera of univalves, the characters first used by Adanson; but among the bivalves, besides the form of the tubes or syphon, he notices the construction of the branchiæ and the presence or absence of a foot.

To our knowledge of the animals which inhabit bivalves, Poli, in his expensive work, the *History of the Shells of the Two Sicilies*, made very important additions. In the construction of his families, which are six in number, he employs merely the characters furnished by the syphon and foot. In the first family the animal has two syphons and a foot; in the second, there

Mollusca. is only one syphon and foot; in the third, a syphon and no feet; in the fourth there is an abdominal syphon and no feet; in the fifth there is a foot but no syphon; while, in the sixth, neither foot nor syphon can be discovered. In the formation of his genera, Poli takes advantage of the various forms of the cloak and the branchiæ.

Cuvier. To the celebrated Cuvier, the conchologist is also under the greatest obligations. By applying his vast knowledge of anatomy to the examination of the molluscous animals, he has unfolded many new conformations of parts, and exhibited many unlooked-for relations. The vast collection of objects, the spoils of all the museums of the continent, which Paris once possessed, lay open to his inspection, and his industry appears to have been equal to the harvest which invited him to labour.

In his first attempts to classify the molluscous animals, as contained in his *Tableau Élémentaire de l'Histoire Naturelle des Animaux* (1798); and his *Leçons d'Anatomie Comparée*, (1800-1805), he employed chiefly the characters which the preceding writers had developed, in his inferior divisions; but in his primary distinctions, he distributed the mollusca into three classes: *Cephalopoda*, having the head covered with tentacula, serving as feet; *Gasteropoda*, with the head free, the animal crawling on the belly; and *Acephala*, having no distinct head.

Some years after the appearance of this classification, Cuvier directed more of his attention to the internal structure of the mollusca, and, by means of accurate dissections, obtained a more intimate acquaintance with the organs and functions of these animals than any of his predecessors had acquired. The information which he thus gained was communicated to the public at different periods, in the well-known publication *Annales du Museum d'Histoire Naturelle de Paris*. These papers, with some additional observations, were at last published in a separate form, under the title *Mémoires pour servir à l'histoire et à l'Anatomie des Mollusques*, Paris, 1816. In the following year he published *Le Règne Animal, distribué d'après son organisation*, in which he arranged the mollusca according to his peculiar views, from characters drawn exclusively from the animal. In the third volume, of what may be termed the third edition of that invaluable work, published in 1830, the same arrangement, with the exception of a few modifications, was adhered to.

He divides the mollusca into six classes, which he terms *Cephalopoda*, *Pteropoda*, *Gasteropoda*, *Acephala*, *Brachiopoda*, and *Cirrhopoda*.

In the class *CEPHALOPODA*, the body is in the form of a sack, open above, containing the branchiæ, with a distinct head, surrounded by fleshy elongations or arms, adapted for moving the body or seizing prey. Into this class, along with the *Sepia* of Linnæus, Cuvier has inserted the multilocular shells of his genus *Nautilus* and the genus *Argonauta*. But it is to be feared, that our knowledge of the testaceous mollusca which inhabit the numerous multilocular shells, is too limited to enable us to assign to all of them their true place in a natural arrangement of animals.

In the second class, termed *PTEROPODA*, the body is closed, the head is destitute of the long fleshy arms which distinguish the animals of the preceding division; two fin-like membranes, situate on the sides of the neck, and on which the branchial tissue is in general spread, serve as organs of motion. There is only one shelly mollusca belonging to this class, viz., the *anomia tridentata* of Forskæhl, now forming a part of the genus *hyalæa*.

The third class, which includes a great number of naked and testaceous mollusca, and to which Cuvier gives the name *GASTEROPODA*, from the circumstance of the belly being formed for crawling, has been subdivided into eight orders, from circumstances connected with the organs of respiration.

In the first order, termed *Pulmones*, which breathe air, *Mollusca.* he has constituted two divisions, the terrestrial and the aquatic. The animals of the former live on land, and were included by Linnæus in his genera *limax* and *turbo*. They are the land shells of most authors. Those of the division, termed aquatic, live in the water, but require at intervals to come to the surface to obtain fresh air. They constitute, with a few exceptions, the fresh water shells of naturalists. In the second and third orders, or *Nudibranches* and *Inferobranches*, the species consist almost entirely of genera formed from the animals which Linnæus and many others included in the genus *doris*. They are naked mollusca, and are likewise destitute of any internal testaceous plate. The fourth order, termed *Tectibranches*, contains animals whose branchiæ, like small leaves more or less divided, are situate on the right side, or upon the back. The animals of this division possess a shell, but it is in general placed beneath the common integuments, such as the genus *Aplysia* and several species of the genus *Bulla*. The fifth order, termed *Heteropodes*, have the gills plumose and dorsal, with the foot compressed and vertical like a fin, with a small portion of it only formed to act as an organ of adhesion, as in the other gasteropoda. The *Pectinibranches* form the sixth order, and are distinguished by the branchiæ, which are like leaves or threads placed parallel in one, two, or three lines, on the surface of the pulmonary cavity, and by having the sexes separate. It includes the whole of the marine species of the Linnæan genera of turbinated univalves. Into this order, Cuvier, from the consideration of other characters, has inserted the genus *Cyclostoma*, which, according to the characters indicated by the respiratory organs, belongs to the *Pulmones*.

In the seventh order, termed *Scutibranches*, the branchiæ are similar to those of the preceding order, but the sexes are united, each individual being capable of impregnating or being impregnated. The shells in general are cup-shaped, and destitute of a lid. It includes the genus *Halyotis*, and many species of the old genus *Patella*. In the last order, called *Cyclobranches*, the branchiæ appear in the form of small leaves or pyramids strung round the under margin of the cloak. They enjoy a hermaphroditism similar to those of the preceding order. The species of the genus *Patella* which are allied to the *vulgata*, and the genus *Chiton*, are included in this order.

In the fourth class, or *ACEPHALA*, he includes the bivalve shells, distributing them into families, from characters nearly similar to those which we have pointed out as having been previously employed by Poli.

The fifth class, termed *BRACHIOPODA*, contains animals, resembling those of the preceding class in having a cloak of two lobes, but these are always open. The branchiæ consist of small leaves placed on the inner margin of each lobe. In place of a foot they have two retractile fleshy arms, which are extensile. This class includes the *Patella unguis* of Linnæus, the genus *Terebratula* and the *Patella anomala* of Müller.

The class *CIRRHIPODA*, distinguished by the articulated filaments with which the animals are furnished, contains the species of the genus *Lepas* of Linnæus. The shells belonging to the Linnæan genera *Sarpula* and *Dentalium*, are transferred to the class termed *Annelides*.

This system of the molluscous animals is unquestionably the most perfect of all those which have been published. But, with all its excellence, we must inform the reader, that many species, nay, whole genera, have their places assigned them in this natural method, merely because the shells occupied a similar position in the artificial system, the form of the inhabitants being unknown.

SECTION IV.—Mixed Systems.

In this section, we shall confine our remarks to the only

Mollusca. system of this kind of any consequence which has hitherto appeared, and which is the production of the late industrious Lamarck, one of the most celebrated zoologists of the French school. The *Système des Animaux sans Vertèbres*, Paris, 1801, of this author, embraces the whole range of animals included in the classes Insecta and Vermes of Linnæus. Where treating of the Mollusca he divides them into two orders. The first, termed *Cephalous*, from possessing a head, includes the univalves. The second, termed *Acephalous*, from the absence of a head, includes the bivalves. This eminent author greatly modified his views, as appears from what he announced in his *Extrait du Cours de Zoologie*, Paris, 1812, the prelude to his last and great work, *Histoire Naturelle des Animaux sans Vertèbres*, the fifth, sixth, and seventh volumes of which refer to the Mollusca, he fortunately lived to finish between the years 1818 and 1822. The arrangement adopted in this invaluable work, has been greatly admired, a circumstance which induces us to give the following synoptical view of its contents.

The species considered by the older naturalists as shells and mollusca, are in this system of Lamarck distributed into three great divisions or classes, which he has denominated CIRRIPEDES, CONCHIFERÆ, and MOLLUSCA. These classes he has subdivided according to the following tabular view :

CIRRIPEDES.

Animalia mollia, capite oculisque carentia, testacea, fixa. Corpus subresupinatum, inarticulatum, tegumenti appendice involutum, disuper brachiis lentacularibus, cirratis, multiarticulatis instructum.

Os subinferum, non prominulum; maxillis transversalibus dentatis per paria dispositis. Brachia numero varia, inequalia, biordinata; singula cernis geminatis, setaceis, multiarticulatis, ciliatis tegumento corneo indutis, pediculo impositis. Anus tubum proboscideum terminans.

Medulla longitudinalis nodosa, branchiæ externæ, interdum absconditæ; circulatio corde vasculisque confecta.

Testa vel sessilis vel pediculo flexili tendineo elevata; valvis pluribus modò mobilibus, modò ferruminatis, tegumenti appendice intus vestitis.

ORDRE PREMIER.—CIRRIPEDES SESSILES.

Leur corps n'a point de pédoncule, et se trouve enfoncé dans une coquille fixée sur les corps marins. La bouche est à la partie supérieure et antérieure du corps.

1. Opercule Quadri-valve.

GEN. Tubicelle, Coronule, Balane, Acaste.

2. Opercule bivalve.

GEN. Pyrgome, Creusie.

ORDRE SECOND.—CIRRIPEDES PÉDONCULÉS.

Leur corps est soutenu par un pédoncule tubuleux, mobile, dont la base est fixée sur les corps marins. La bouche est presque inférieure.

(1.) Corps incomplètement enveloppé par sa tunique. Sa coquille composée de pièces contiguës, laisse à l'animal une issue libre, lorsqu'elle s'ouvre.

GEN. Anatife, Pouce-pied.

(2.) Corps tout à fait enveloppé par sa tunique, mais qui offre une ouverture antérieure. Sa coquille, formée de pièces séparées, n'a pas besoin de s'ouvrir pour la sortie des bras de l'animal.

GEN. Cinéras, Otion.

CONCHIFÈRES.

Animalia mollia, inarticulata, in testa bivalvi perpetuo affixa, capite oculisque nullis; ore nudo, abscondito, partibus solidis destituto; pallio amplo, corpus totum amplexante, lobos duos laminiformes formante; laminis vix liberis vel antice coadunatis. Generatio ovo-vivipara; copulatio nulla.

Branchiæ externæ, intra corpus et pallium reconditæ. Circulatio simplex; cor uniloculare. Gangliones aliquot rari; nervi varii; at chorda medullaris nodosa nulla. Tes-

ta semper bivalves, animal penitus vel partim recondens, Mollusca. modo libera, modo affixa; valvis sæpissime cardine vel ligamento marginali unitis. Partes testaceæ, accessoriæ, vavis alienæ, testam interdum amplificans.

ORDRE I.—CONCHIFÈRES DIMYAIRES.

Ils ont au moins deux muscles d'attache. Leur coquille offre intérieurement deux impressions musculaires séparées et latérales.

1. Coquille régulière, le plus souvent équivalve.

(a) Coquille en général béante aux extrémités latérales, ses valves étant rapprochées.

(*) *Conchifères crassipèdes*. Leur manteau a ses lobes réunis par-devant, entièrement ou en partie; leur pied est épais, postérieur; le baillement de leur coquille est toujours remarquable, souvent considérable.

(1.) Coquille, soit contenue dans un fourreau tubuleux, distinct de ses valves, soit entièrement, ou en partie incrustée dans la paroi de ce fourreau, soit saillante au-dehors.

Les Tubicolées.

(2.) Coquille sans fourreau tubuleux.

(a) Ligament extérieur.

(+) Coquille, soit munie de pièces accessoires, étrangères à ses valves, soit très baillante antérieurement.

Les Pholadaires.

(++) Coquille sans pièces accessoires, et baillante seulement aux extrémités latérales.

Les Solénacées.

(b) Ligament intérieur.

Les Myaires.

(**) *Conchifères tenuipèdes*. Leur manteau n'a plus ou presque plus ses lobes réunis par-devant; leur pied est petit, comprimé; le baillement de leur coquille est souvent peu considérable.

(+) Ligament intérieur, avec ou sans complication de ligament externe.

Les Mactracées, Les Corbulées.

(++) Ligament uniquement extérieur.

Les Lithophages, Les Nymphacées.

(b) Coquille close aux extrémités latérales, lorsque les valves sont fermées.

(***) *Conchifères lamellipèdes*. Leur pied est applati, lamelliforme; non postérieur.

Les Conques, Les Cardiacées, Les Arcacées, Les Nuyades.

(2) Coquille irrégulière, toujours inéquivalve.

Les Camacées.

ORDRE II.—CONCHIFÈRES MONOMYAIRES.

Ils n'ont qu'un muscle, qui semble traverser leur corps. Leur coquille offre intérieurement une impression musculaire subcentrale.

1. Section. Ligament marginal, allongé sur le bord sublinéaire.

(a) Coquille transverse, équivalve, à impression musculaire allongée, bordant le limbe supérieur.

Les Tridacnées.

(b) Coquille, soit longitudinale, soit subtransverse, à impression musculaire resserée dans un espace isolé sans border le limbe.

(+) Ligament au bord latéral de la coquille et toujours entier.

Les Mytilacées.

(++) Ligament au bord inférieur de la coquille, ou divisé.

Les Malléacées.

II. Section. Ligament non marginal, resseré dans un court espace sous les crochets, toujours connu, et ne formant point un tube tendineux sous la coquille.

(a) Ligament intérieur ou demi intérieur. Coquille régulière, à test compact non feuilleté.

Les Pectinides.

(b) Ligament intérieur ou demi intérieur. Coquille irrégulière, à test feuilleté, quelquefois papyracé.

Les Ostracées.

III. Section. Ligament, soit nul ou inconnu, soit représenté par un cordon tendineux qui soutient la coquille.

(a) Ligament et animal inconnus. Coquille très-inequivalve.

Les Rudistes.

(b) Coquille adhérente, soit immédiatement, soit par un cordon

tendineux qui la soutient et lui sert de ligament; l'animal ayant deux bras opposés, cilies et cirreux.

Les Brachiopodes.

MOLLUSQUES.

Animalia mollia, inarticulata, antice capitata; capite plus minusve prominulo, oculis tentaculisque scœpissime instructo, aut brachiis pluribus superne coronato. Os, vel breve, vel elongatum, tubulosum, exsertile, scœpius partibus duris armatum. Pallium varium; modo marginibus liberis ad corporis latera, modo lobis in saccum coadunatis corpus partim vaginans.

Branchiæ variæ, raro symmetricæ; circulatio duplex, particularis et generalis. Cor uniloculare; interdum auriculis duabus divisus et valde remotis. Chorda medullaris nodosa nulla; at gangliones sparsi rariusculi, nervique varii.

Corpus modo externe nudum, et intus vel partibus solidis destitutum, vel testam aut corpora aliquot dura recondens; modo extus testa vaginante vel obumbrante tectum. Testa nunquam valvis duabus oppositis et cardine marginali unitis composita.

I. ORDRE.—LES PTEROPODES.

Point de pied pour ramper, ni de bras pour se trainer ou saisir le proie. Deux nageoires opposées et semblables, propres à la natation. Corps libre, flottant.

1. Hyale; 2. Clio; 3. Cléodore; 4. Limacine; 5. Cymbulie; 6. Pneumodernie.

II. ORDRE.—LES GASTÉROPODES.

Animaux à corps droit, jamais en spirale ni enveloppé dans une coquille qui puisse le contenir en entier; ayant sous le ventre un pied ou disque musculé uni au corps à peu près dans toute sa longueur, et servant à ramper.

Les uns nus, d'autres ombragés par une coquille dorsale, non engainante, et d'autres encore contenant une coquille plus ou moins cachée dans leur manteau.

I. Section.—Branchies, quelle que soit leur position, s'élevant, soit en filets, soit en lames, soit en peignes ou panaches. Elles ne respirent que l'eau.

(Hydrobranches.)

(a) Branchies extérieures, placées au-dessus du manteau, soit sur le dos, soit sur ces côtés, et n'étant point dans une cavité particulière.

Les Tritoniens.

(b) Branchies extérieures, placées sous le rebord du manteau, et disposées en série longitudinale, soit autour du corps, soit d'un seul côté; n'étant pas non plus dans une cavité particulière.

Les Phyllidiens, Les semi-Phyllidiens.

(c) Branchies placées dans une cavité particulière sur le dos située antérieurement près du cou.

Les Calypttracions.

(d) Branchies placées dans une cavité particulière, vers la partie postérieure du dos, et recouvertes, soit par le manteau, soit par un écusson operculaire.

+ Point de tentacles.

Les Buléens.

++ Des tentacules.

Les Laphysiens.

II. Section. Branchies rampantes, sous la forme d'un réseau vasculaire, sur la paroi d'une cavité particulière dont l'ouverture est un trou que l'animal contracte ou dilate à son gré. Elles ne respirent que l'air libre.

(Pneumobranches.)

Les Limaciens.

III. ORDRE.—LES TRACHÉLIPODES.

Le corps contourné en spirale dans sa partie postérieure, cette partie étant séparée du pied, et toujours enveloppée dans une coquille. Le pied libre, aplati, attaché à la base inférieure du cou, ou à la partie antérieure du corps, et servant à ramper. Coquille spirivalve engainante.

I. Section. Trachéliopodes sans siphon saillant, et respirant en général par un trou. La plupart phytiphages et munis de machoi-

res. Coquille à ouverture entière, n'ayant à sa base ni échancrure dorsale subascendante ni canal.

* Trachéliopodes ne respirant que l'air. Coquille spirivalve, mutique non distinctement nacrée.

(a) Ceux qui habitent hors des eaux.

Les Colimacés.

A quatre, } Tentacules.
A deux }

(b) Ceux qui vivent dans les eaux, mais qui viennent respirer l'air à leur surface. Coquille à bords de l'ouverture jamais réfléchis.

Les Lymnéens.

** Trachéliopodes ne respirant que l'eau. Branchies saillantes en forme de filets, de lames ou de hupes, dans la cavité branchiale. Coquille souvent nacrée et souvent aussi ayant des parties protubérantes à sa surface.

(a) Coquille fluviatile, operculée, dont le bord gauche n'imité pas une demi-cloison.

(+) Coquille à bords désunis.

Les Mélaniens.

(++) Coquille à bords réunis.

Les Péristomiens.

(b) Coquille fluviatile ou marine dont le bord gauche imite une demi-cloison.

Les Néritacés.

c. Coquille marine, dont le bord gauche n'imité pas une demi-cloison.

(+) Coquille flottante à la surface des eaux.

Les Janthines.

(++) Coquille non flottante, ayant l'ouverture très évasée; point de columelle.

Les Macrostomes.

(+++ Ouverture sans évasement particulier; des plis à la columelle.

Les Plicacés.

(++++ Point de plis à la columelle.

(a) Les bords de l'ouverture réunis circulairement.

Les Sculariens.

(b) Les bords de l'ouverture désunis.

Les Turbinacés.

II. Section. Trachéliopodes à siphon saillant, et ne respirant que l'eau qui parvient aux branchies par se siphon. Tous sont marins zoophages, dépourvus de mâchoires et munis d'une trompe rétractile. Coquille spirivalve, engainante, à ouverture, soit canaliculée, soit échancrée ou versante à sa base.

(a) Coquille ayant un canal plus ou moins long à la base de son ouverture, et dont le bord droit ne change point de forme avec l'âge.

Les Canalifères.

(b) Coquille ayant un canal plus ou moins long à la base de son ouverture, et dont le bord droit change de forme avec l'âge et a un sinus inférieurement.

Les Ailéés.

(c) Coquille ayant un canal court, ascendant postérieurement, ou une échancrure oblique en demi-canal à la base de son ouverture, ce demi-canal se dirigeant vers le dos.

Les Purpurifères.

(d) Point de canal à la base de l'ouverture, mais une échancrure subdorsale, et des plis sur la columelle.

Les Columellaires.

(e) Coquille sans canal, mais ayant la base de son ouverture échancrée ou versante, et ses tours de spire étant larges, comprimés, enroulés de manière que le dernier recouvre presque entièrement les autres.

Les Enroulées.

IV. ORDRE.—LES CÉPHALOPODES.

Manteau en forme de sac, contenant la partie inférieure du corps. Tête saillante hors du sac, couronnée par des bras non articulés, garnis de ventouses, et qui environnent la bouche. Deux yeux sessiles, deux mandibules cornées à la bouche; trois cœurs; les sexes séparés.

1. DIVISION.—CÉPHALOPODES POLYTHALAMES.

Ils ont une coquille multiloculaire, partiellement ou complètement intérieure, et enchassée dans la partie postérieure de leur corps.

Mollusca. • Coquille multiloculaire à cloisons simples.

Leurs cloisons ont les bords simples et n'offrent point de sutures découpées et sinueuses sur la paroi interne du test.

(1.) Coquille droite ou presque droite : point de spirale.

Les Orthocères.

GEN. Bélemnite, Orthocère, Nodosaire, Hippurite, Conilite.

(2.) Coquille partiellement en spirale ; le dernier tour se continuant en ligne droit.

Les Lituolés.

GEN. Spirale, Spiroline, Lituole.

(3.) Coquille semi-discorde, à spire excentrique.

Les Cristacées.

GEN. Rénuline, Cristellaire, Orbiculaire.

(4.) Coquille globuleuse, sphéroïdes ou ovale ; à tours de spire enveloppans ou à loges réunies en tunique.

Les Sphérulés.

GEN. Miliolite, Gyrogone, Mélonie.

(5.) Coquille discoïde, à spire centrale, et à loges rayonnantes du centre à la circonférence.

Les Radiolés.

GEN. Rotalie, Lenticulaire, Placentule.

(6.) Coquille discoïde, à spire central, et à loges qui ne s'étendent pas du centre jusqu'à la circonférence.

Les Nautilacées.

GEN. Discorbe, Sidérolite, Polystomelle, Vorticiale, Nummulite, Nautilite.

** Coquille multiloculaire, à cloisons découpées sur les bords.

Les Ammonées.

GEN. Ammonite, Orbulite, Ammonocérate, Turrilite, Baculite.

2. DIVISION.—CÉPHALOPODES MONOTHALAMES.

Coquille uniloculaire, tout-à-fait extérieure, et enveloppant l'animal.

GEN. Argonaute.

3. DIVISION.—CÉPHALOPODES SÉPIAIRES.

Point de coquille, soit intérieure, soit extérieure. Un corps solide, libre, crétacé ou corné, contenu dans l'intérieur de la plupart de ces animaux.

GEN. Poulpe, Calmaret, Calmer, Sèche.

V. ORDRE.—LES HÉTÉROPEDES.

Corps libre, allongé, nageant horizontalement. Tête distincte ; deux yeux. Point de bras en couronne sur la tête ; point de pied sous le ventre ou sous la gorge pour ramper. Une ou plusieurs nageoires, sans ordre régulier et non disposées par paires.

GEN. Carinaire, Firole, Phylliroé.

The authors of the first class of conchologists which we have mentioned, employ exclusively the characters furnished by the shell, and scarcely deign to tell us that there is an animal attached to that shell. The authors of our third class are anxious to keep the shell out of view, and draw their distinctions from the animal ; but they have failed in the attempt. In extreme cases, the characters of the shell are resorted to in the absence of distinctions furnished by the animal.

Lamarck perceived the inconvenience of separating these two modes of examining molluscous animals, and fortunately formed a very natural combination. We shall give his character of the genus *Patella*, as a specimen of this mixed system.

Patella.

Corpus testa univalvi penitus obtectum ; capite tentaculis duobus acutis, basi externa oculiferis. Branchiæ infra veli marginem per totam corporis periphæriam seriatim dispositæ. Orificia pro generatione et ano ad latus dextrum anticum.

Testa univalvis, non spiralis, animal obumbrans, clypi-

ata vel retuso conica, imperforata ; fissura marginali destituta ; cavitate simplici ; apice antérieur recurvo.

In this manner the generic character is dependent equally on the shell and the contained animal, and that genus in a system is consequently not sufficiently established in which both these characters are not included. How many genera are in this imperfect state ! Were the same plan followed in the description of species, everything we could wish for would be detailed ; and our knowledge of the forms of molluscous bodies would approach to perfection. How much is it to be wished that this plan of Lamarck's were generally adopted in this country ! conchology would assume a new aspect, and the number of his votaries would rapidly increase.

The reader will have perceived, in the course of the comparative review of those systems which we have enumerated, that we have refrained from making any remarks on their comparative excellence. This deficiency we now propose to supply in the following observations.

The authors who have arranged testaceous bodies, without reference to the animals that reside in them, appear to have mistaken the house for the inhabitant, and the thing formed for the being that produced it. They have torn asunder objects which are closely related, and united others which differ in structure and economy. These are necessary consequences of an artificial system, and they become more obvious in proportion as we descend in the scale of being.

The examination of shells, according to this method, may be viewed as the study of the osteology of the mollusca. It has not for its object the investigation of living matter, but of dry bones. Nor has it any of those advantages which result from the study of the osteology of the vertebral animals. A knowledge of the bones of these animals enables us to ascertain many of their primary functions, the nature and extent of their powers of motion, and even the food on which they subsist. But our knowledge of shells does not enable us to say, whether the animal can crawl or swim ; whether it feeds on plants or animals. The reason is obvious. All the muscles inserted upon the shell are either mere organs of adhesion, or destined to open and shut the valves. None of those muscles connected with any of the primary organs have any connection with the shell. That the shell furnishes several most important characters, we readily grant ; but we are here reasoning against the propriety of attending to the shell, to the exclusion of the animal, and, to this extent, our reasoning appears to be conclusive.

We are aware, that, in the other departments of natural history, the appearances which the external parts of an animal exhibit are constantly employed in the construction of orders and genera, and all the intermediate divisions. Thus, for example, the bill, feet, and feathers of birds, furnish the characters by which they are arranged in the system. Here, however, it must be observed, that the combined information yielded by these parts, makes us acquainted with the habits and organization of a bird. By means of these we can judge, and with certainty, not merely of its internal structure, but the places which it frequents, and the food which it consumes. Hence these characters may be applied with equal propriety in an artificial as in a natural method. But what opinion would we form of that ornithologist, who could readily inform us that the cormorant has fourteen tail feathers, and the shag only twelve, but who was ignorant of the haunts of these birds, their food, and the number of their young. We might prize him as a companion in surveying a museum, but he is alike a stranger to science and nature.

Nor can we feel more respect for the student of mere shells. He may be able to tell us the number of whorls in a spiral univalve, or the form of the hinge in a bivalve ; but if he knows not the nature of the organs of respiration, digestion, and reproduction of the animal to which the shell

Mollusca. belongs, and contentedly remains in this ignorance, he has yet to learn the value of method in natural history. He cherishes with mistaken fondness the maxim of Linnæus, "Nomina nosse oportet qui rem scire velit," while he overlooks a more important object, expressed in the motto of the Linnæan Society, "Naturæ discere mores."

These remarks apply to the conchological labours of Linnæus and his followers, who have devoted their whole attention to the arrangements of the shells, without attending to the animals. We know that some of the admirers of the Swedish naturalist presume to say, "But our great author was not wholly inattentive to the creatures for which the beautiful and endless diversified receptacles that he had characterised were designed. Among the generic marks was included the name of the molluscous inhabitant; or, where the animal differed from any which had a place in other parts of his system, he described it at length." (Linn. *Trans.* vol. vii. 175.) Now, to what does all this attention of Linnæus amount? In all the species which he has described, he has only noticed the animals of four of these, and in a very slight manner; and, with regard to the name of the molluscous inhabitant which he included in his generic marks, we hesitate not to say, that by this union he has betrayed carelessness. To many British ears these terms may sound harsh, but the proof of their correct application in the present instance will be abundantly evident, if we examine the references to the animals of a few of his genera. The genus *chiton* is thus characterised; "Animal Doris. Testæ plures, longitudinaliter gestæ, dorso incumbentes." Are we not led to conclude from this character, that the animals of the *chiton* exactly resemble the animals of the *doris* genus, with the addition of the shells? If this be the case, how artificial is that system which places these two genera in separate orders! Upon turning, however, to the genus *doris* among his *vermes mollusca*, we find the following characters assigned to it; "Corpus repens, oblongum, subtus planum. Os antice subtus. Anus postice, supra cinctus ciliis. Tentacula duo, supra corpus antice intra foramina retractilia." Now, the fine fringes around the anus of the *doris*, which are the branchiæ of the animal, and form the essential character of the genus, are not to be found in the animals of the *chiton*, whose branchiæ are in the form of leaves placed along the margin of the body, and the anus is a simple pore.

According to the generic character of the *mya*, the animal is an *ascidia*, with the appendage of a shell. Upon turning to the genus *ascidia*, we find it said, "Corpus fixum, teretiusculum, vaginans. Aperturæ binæ, ad summum; altera humiliore." To prove the impropriety of referring the animal of the *mya* to the genus *ascidia*, we shall only mention, that the former has a foot, and possesses a locomotive power; the latter has no foot, remains immovably attached for life upon the substance to which it at first adhered, and depends on the accidental bounty of the waves for all its nourishment.

The animals of nearly all the univalves are represented as belonging to the genus *limax*. But, with the exception of the restricted genus *helix* and *bulimus*, the animals of the univalves are all generically different from the *limax*. Their tentacula are generally two in number, with the eyes at the base; while the tentacula are four in the *limax*, with the eyes at the tips of the two longest. These examples will suffice to establish a truth so palpably obvious.

The principal objection against this system of employing the shell, to the exclusion of the animal, arises from the fact, that nature has not drawn a line of distinction between the mollusca and the testacea. Thus, many of the *vermes mollusca* of Linnæus include shells in their bodies, as the *aplysia*; and many of his *vermes testacea* likewise are soft on the outside, the shell being inclosed by the integuments, as the *helix laevigata*, now constituting the genus *VELUTINA*.

We have another objection to this artificial system, and one which we consider of great force; that, wherever it prevails, the form and habits of the animal are overlooked. How fully is this truth illustrated in the works of the testaceologists of this country! We might examine all their writings, from the *Pinax* of Merret to the *Descriptive Catalogue* of Maton and Raket, including the works of Pennant, Berkenhout, Da Costa, and Donovan, and learn little more, besides the *habitat*, than that to every shell there is an animal attached. Of this charge the names of Lister and Montagu stand acquitted. The former has given us several good dissections, and the latter minute descriptions of the testaceous animals.

Whilst, in the preceding remarks, we have objected to all arrangements taken exclusively from the characters of the shell, we also disapprove of those systems founded exclusively on the characters of the animal. By the former class of methodists, the simplicity of nature is sacrificed to their peculiar views, and, by the latter, practical utility is disregarded. Devoting their whole attention to the animal, the later naturalists have overlooked the house in which it resides; the roof which shelters it from the blast; and the walls which guard it from its foes. The former observers possessed very limited views of nature, and erected systems obviously artificial. To the systems of the latter, the same objections will apply. Thus, for example, among the univalves of Adanson, the families are formed from the position of the eyes chiefly. That the black points which we witness at the tips or at the base of the tentacula are actually eyes, we readily admit; but what influence have these eyes on the habits of the animal? or rather, does a change of position of these organs occasion a corresponding change in the habits of the animal? Unless this is answered in the affirmative, we must consider such characters as equally artificial with any employed by Linnæus or his followers, since they have no relation to any of the primary functions of life.

The employment of characters taken exclusively from the animal is attended with so many practical difficulties, that it never can be introduced into general practice. If we find a shell thrown ashore, the animal may be dead, or it may refuse for a time to display its organs, and prevent us from arriving at its name and history. This defect, however, is partly remedied when we can call to our aid the characters furnished by the shell.

Another objection against this method arises from the well known difficulties attending the preservation of the soft parts of molluscous animals. To dry these, destroys their form and texture; to inject them is impracticable; and when put into spirits of wine, they generally appear a shrivelled mass. But the coverings of these animals are durable, and, since they form a part of the animal; since they are produced at first along with it, increase by the addition of new matter from its body, and continue attached to it for life; we must condemn any classification from which the shell is excluded.

From these remarks, it will be obvious, that we consider the mixed system as the most natural and the most useful. It possesses all the advantages to which the other systems lay claim, while it is free from their defects. It withdraws part of our attention from the shell, because it is destitute of peculiar vessels, and possesses no vital energy, to fix it on those organs of the animal which are subservient to its existence. It leads us to examine the whole animal, instead of certain parts of it merely, and has a tendency to excite us to become acquainted with the manners of a tribe, from which, imperfect and artificial systems have hitherto withdrawn our attention.

VALUE OF THE CHARACTERS EMPLOYED.

It is of the utmost importance in the formation of any arrangement of natural bodies, to have an exact idea of the

Mollusca. relative value of the characters used, and of their true subordination. This is a subject of vast moment, and too little attended to by naturalists. We do not here consider that character as of the highest kind, which is the most general, but that which has the greatest influence over the faculties and instincts of the animal. Had this subject been studied with greater care, the science of conchology would, at this period, have been in a more flourishing condition. To ascertain, in some degree, this subordination of character, is the object of the following observations.

The division of the testaceous mollusca into three orders, as adopted by Linnæus, is confessedly artificial. The Multivalvia of that author possess no characters in common, neither can they boast of a general resemblance. The first genus, *Chiton*, consists of animals which belong to the cephalous and gasteropodous mollusca. The animals of the genus *Lepas* approach more nearly to the crustacea than the mollusca; while the animals, inhabiting the genus *Pholas*, belong to the acephalous mollusca, and are closely connected with the *Myæ* and *Solenes*. The shells of the first genus are merely calcareous scales, arranged transversely on the back of the animal. The shells of the second genus are variously articulated, fixed, and either sessile or pedunculated. The shells of the third genus are bivalves, with a few accessory calcareous plates. It is to be hoped that modern conchologists will avoid so incongruous a combination.

The two remaining divisions of Linnæus, the bivalves and univalves, are not only obvious, but natural. They indicate the existence of certain forms peculiar to the animals whose shells are thus separated in the system. The univalve shells are inhabited by animals which possess a head, and whose organs of motion are either tentacula situated on the head, or a foot spread over the belly, as in the slug. The animals of the bivalve shells, on the other hand, are destitute of a head; some of them have no locomotive power; and, in others, the organ of motion is a fleshy foot, which the animal can protrude at pleasure. These circumstances point out the connection which subsists between the organs of the animal, and the external forms of the shell; a connection which, in every system, ought to be carefully attended to.

Univalves. It is somewhat difficult to point out, among the univalves, the true subordination, or relative importance of the characters employed by conchologists in describing them. We have much to learn of their anatomy, and hence we cannot with certainty point out the relation of the parts of the shells to the organs which those parts protect. The form and structure of the mouth of the shell, however, may be expected to furnish characters of the first-rate importance, and have always attracted the notice of the student of testaceous bodies. The very shape of the animal, together with its ordinary habits, must necessarily depend, in a great measure, on the form of the mouth.

Canaliculated shells. In many genera, the mouth of the shell towards the base is produced, and terminates in a groove or beak. These univalves are termed *canaliculated*, and are readily distinguished from those whose mouth is *entire*. The differences in the form of the shell in these two divisions is an index of equally remarkable differences in the form of the animals. The canaliculated shells contain animals possessed of an elongated tube for the purposes of respiration, and this canal is destined for its reception and protection when expanded. The animals whose shells are destitute of this canal, are likewise destitute of this lengthened respiratory tube. Circumstances of this kind induce us to believe, that shells, agreeing in external form, in general, contain animals of a similar organization. We consider this division of the univalves into canaliculated and entire, as obvious and natural.

The next character, in point of importance, appears to depend on the direction of the revolutions of the spire. In general, when a spiral univalve is placed upon its base, or

mouth, with its summit towards the observer, the mouth will open on the right side of its axis or pillar, and the whorls will be observed to revolve from right to left, beginning at the base, and ending at the summit. These shells are termed *dextral*. In a few shells, however, this order is reversed. The mouth occurs on the left side of the pillar in the above-mentioned position, and the whorls from the mouth to the summit revolve from left to right. Shells of this sort are termed *sinistral*, sometimes also heterostrophe or heteroclite, and are generally called by dealers *unique*.

In the *dextral shells*, the animals have the external openings of the rectum, penis, and uterus, on the right side of the body, and the heart on the left. In the *sinistral shells*, these organs are placed on the opposite sides. Thus the openings of the rectum and organs of generation are on the left side, while the heart is situated on the right. Here again we have an external character impressed on the shell, which indicates certain arrangements in the organs of the animals. We are aware that some conchologists consider the sinistral shells as accidental varieties, and on that account regard the character which is indicated as of inferior importance. Bosc, indeed, says, "La cause de cette variation dans la direction des spires, vient des circonstances dans lesquelles s'est trouvé l'animal au moment de sa naissance, et d'un obstacle qu'il a trouvé lorsqu'il a voulu tourner sa tête du côté que la nature lui a indiqué." This explanation might have been received, had such changes in the direction of the whorls been confined to one individual or two, of particular species. But when we observe all the individuals of particular species, nay even of genera with their whorls thus invariably reversed, we are disposed to regard the occurrence as connected with the primary structure of the animal, and not as the result of accident. Besides, the viscera of the animal of a reversed shell are not placed in the same position in relation to its back or belly, as the animals of the dextral species. A simple change of direction in the spire, therefore, will not convert a dextral into a sinistral species, and the character must be considered as of a higher order than those employed for the separation of the species merely. We consider sinistral shells as belonging to distinct genera from those which are dextral, it being inexpedient to make use of the character for higher divisions.

Among many of the univalves, the animal is furnished with a lid, by means of which it can close up the entrance of the shell after it has withdrawn itself into the cavity. It is in general corneous, sometimes also calcareous. It is usually flat, and attached to the superior and posterior part of the foot of the animal. The shells which possess this lid are generally termed *operculated shells*. They must not be confounded with those land shells of which the animals form a temporary covering to the mouth, previous to winter, for the purpose of protecting them from the vicissitudes of the weather. This lid, in the former case, is permanent, in the latter deciduous; in the former it adheres to the animal, being in connection with it; in the latter only to the margins of the mouth of the shell.

This character was first employed by Adanson in the construction of the second section of his class univalves, and has been more or less attended to by succeeding conchologists. It is certainly a very general character, and at first sight might be supposed worthy of forming some of the higher divisions. It appears but rarely in the land shells, more frequently in fresh water shells, and generally in the marine species. It does not, as yet, appear to be connected with any peculiar organization, although it must influence to a certain extent the economy of the animal. Were we however, to employ it in higher divisions than generic ones, some confusion would certainly arise. It would cause the separation of many genera which are nearly allied, and even divide several natural families. Thus, for example,

Mollusca. among the porcellaneous shells, it would separate the *olives* from *cones*, the former being destitute of an operculum, while the latter possess one. These two genera, however, belong to a natural family, the animals of both genera having a respiratory tube upon the head, and the eyes placed on the sides of the tentacula, instead of being situated, as in the other gasteropoda, on the tips or at the base. This circumstance is calculated to convince us of the necessity of caution in the admission of characters. These may at first appear to be of extensive occurrence, and well adapted for the formation of families, but unless they exercise some visible influence on the animal, they can never be employed with propriety in a natural system, however convenient they may be in an artificial arrangement. Operculated shells may be considered as generically different from those which are destitute of that organ, without any injury to the natural method. It would even, in many instances, be convenient.

Amongst univalve shells, considerable differences are observable in the shape and position of the cavity of the shell. In some cases this cavity is simply conical, while in others it is conico-tubular, either revolving horizontally round a centre, or spirally twisted upon an axis or pillar. These circumstances furnish characters of great importance in an artificial system, as by means of them all testaceous bodies may be arranged into two tribes, the one possessing a pillar, round which the tube of the shell is twisted, while the other is destitute of any pillar. The former have been termed *Stulidia*, the latter *Astulidia*. As a natural character, however, these distinctions are of inferior importance, and, if employed would occasion a separation between the genera *Planorbis* and *Lymnæa*, which are demonstrated by Cuvier to be nearly related. In the formation of genera, it may be employed with advantage, even in a natural system, aided by the structure of the pillar, and the direction of the whorl.

The last character which we have to notice while speaking of the univalves, depends on the circumstance of the cavity being entire, or divided into chambers, being *unilocular* or *multilocular*. In the multilocular testacea there are a number of transverse plates, in some species perforated, in others entire, which cross the cavity of the shell, and, in general, divide the external cavity, in which the animal resides, from the older and smaller ones, from which it has receded. In an artificial arrangement, such distinctions may be employed with advantage, even in the formation of the primary divisions, but we entertain doubts as to the propriety of using them in a strictly natural method. We are in a great measure ignorant of the animals which inhabit the multilocular shells, yet as far as our knowledge goes, we are induced to regard the distinction as merely conventional, and as unconnected with any peculiar order of organization. Such a division may be useful in the present state of the science, and may be permitted on that account; but in proportion as our knowledge of the mollusca advances, this distinction will be deemed inexpedient. Indeed, were this division adopted, the genera *Argonauta* and *Nautilus* would be torn from each other, although they are, by Cuvier and many others, regarded as members of a family of cephalopodous mollusca. The *Nautilus lacustris* of Lightfoot, now constituting the genus *SEGMENTINA*, would, in that case, likewise be separated from the genus *Planorbis*, with which it is very closely allied. In the meantime, until our knowledge of the multilocular testacea arrives at a greater degree of perfection, such divisions may be employed as convenient, and of easy application.

The preceding remarks apply to those shells which belong to the cephalous mollusca. Among the bivalve shells, which belong to the acephalous mollusca, the characters which they exhibit are of very different degrees of importance. Here, as among the univalves, the appearance of the shell enables us to form an idea of the organization of the

animal, so that the characters thus furnished by the shell may be safely employed in a natural system. Mollusca.

The bivalve shells, in general, possess the faculty of moving from one place to another, or of attaching themselves to rocks and stones, by means of temporary threads. These are termed *free* shells. But there are others which secrete at their birth a calcareous cement, which unites the shell to the rock or stone immoveably for life. These last are known by the name of *fixed* shells. If we thus consider the difference in the economy of these two divisions of bivalves, we may reasonably expect to find corresponding differences in their organization. The free shells contain animals endowed with locomotion, and by consequence with feet. In few of the animals which inhabit fixed shells can a foot be observed. They are more simple in their organization than the free shells, and are destitute of absorbing or ejecting syphons, the place of these being supplied by holes in the duplicature of the cloak. This last distinction, however, is not peculiar to the fixed shells, although found in all of them.

Among the free shells, a very important circumstance occurs, which we have already noticed, viz. that some of these adhere to rocks and stones by means of temporary threads produced by the animal. They are termed *byssiferæ*. Independent of the utility of this power of producing threads of attachment, to the economy of the animals, the byssiferæ must possess at least three organs of which the other testaceous mollusca are destitute. The first of these is a gland for the secretion of the substance of which the threads are formed; the second, a foot so constructed as to be capable of spinning these threads and fixing them to the rocks or other bodies to which they are intended to adhere; and the third is a muscle in the animal to which the inner end of these threads may be attached, and which muscle, in general, has the power of contraction and elongation. This character, then, appears perhaps of the very highest order, so that, in a natural arrangement, we might divide the molluscos bivalves into such as spin threads of attachment, and such as do not. We must, however, confess, that the byssiferæ have scarcely any other subordinate characters in common, to warrant such an arrangement.

In general, the valves of which the shell consists close upon each other in such a manner as to leave no opening. In a few genera, however, the valves do not close upon each other at one end, and sometimes at both; the point of union being at one side or in the middle. The former are termed *close* shells, the latter *gaping* shells. The character of gaping, so very obvious in the shell, is an index of equally important distinctions which prevail in the animal. In the gapers, the syphons, or the absorbing and ejecting pipes, are two in number, and very long, and frequently united. The foot is contained in a sheath, from which it issues at the pleasure of the animal. Besides, the branchiæ are always united, and equal in length to the tubes. This character appears, therefore, equally important as the former. It has hitherto been employed in the construction of specific characters merely, rarely of genera.

When the two valves are of the same size and form, the shell is said to be *equivalve*; but when the one valve differs from the other in these particulars, the shell is said to be *inequivalve*. This character, so obvious and so commodious, is not the index of any peculiar organization of the animal. If employed in the higher divisions, it would separate closely connected genera, and destroy some natural alliances. The inequivalves, however, are for the most part irregular in their growth. The molluscos inhabitants have no lengthened syphon nor foot.

When we examine the inner surface of bivalves, we observe some spots of a different colour and lustre from the general surface. These are the places to which the muscles adhered, which connected the animal with the shell, and are

Mollusca. termed *muscular impressions*. They are either separate and lateral, subcentral, or simple, or composite. This character was long employed by conchologists in their specific distinctions, and sometimes in the formation of the genera. It has been more recently employed by Lamarck, as a character of the first importance in the division of the bivalves. He forms these shells into two sections, the first containing those shells which have the muscular impressions separate and lateral, and the second such as have only one subcentral, simple, or compound impression. However highly we respect the conchological labours of this naturalist, we cannot join with him in the present instance, and elevate a subordinate character to a primary rank. If, by muscular impressions, he means those marks impressed on the valves of the shells by the muscles which serve to close it, then his character is unconnected with any of the primary functions of the inhabitant. For is it of much consequence whether the valves be brought into contact by the action of one muscle or by the assistance of two? In so far, the character is evidently artificial, when the impressions of the abductor muscles only are employed. But he evidently uses the term in a more extensive sense, to refer to those impressions left on the shell by some of the other muscles by which the animal is attached to it. To the mere conchologist, these marks are of a very uncertain import, and can never enable him to construct natural families, and the student of the mollusca will employ more important distinctions. If we are to take all the muscular impressions into account, the arrangement of Lamarck must undergo great alterations. Let us take the common mussel as an example. It is placed by the French Conchologist in the second section, as having only one muscular impression, although no less than four muscles adhere to each valve, destined for the performance of very different functions. The largest impression, which is situate near the obtuse end of the shell and towards the posterior margin, belongs to the abductor muscle, employed in closing the valves. Connected with this impression there is a tongue-shaped mark, reaching nearly to the ligament. This mark is occasioned by one of the lateral muscles for supporting the byssus, and by one of the lateral muscles of the foot. The other muscle for supporting the byssus, is inserted under the teeth which occur at the beak. There is even another mark of adhesion on the margin of the shell, irregularly denticulated, occasioned by the fringed margin of the cloak, which is there united with the shell. This mark may be termed the *marginal impression*. To which of these marks then are we to attach the greatest importance? To the impression of the one abductor muscle, which is common to all shells, —to the marks of the muscle of the byssus, or to the indented mark of the fringed margin of the cloak. If we attend farther to Lamarck's arrangement, we shall find the Camacea separated from the Ostreacea, although the two families possess numerous external and internal points of resemblance. We regard the muscular impressions as furnishing a convenient character for the construction of genera, and the discrimination of species, but it is not worthy to occupy so high a rank as Lamarck has assigned to it.

As intimately connected with the muscular impressions, we may here notice the *ligament*. It is a horny elastic membrane, which serves to open the valves, when the adductor muscle relaxes. It is placed on the exterior margin in some shells, and is concealed in others. When external, it is stretched when the shell is closed, and when it is internal, it is compressed in similar circumstances. This character is very useful in the construction of genera, but it ought never to be employed in any of the higher divisions. It is not the index of any peculiar organization, neither does it serve to unite natural families. Lamarck, without due consideration, regarded it as next in importance to the muscular impressions.

Mollusca. The *teeth* of the hinge of bivalves, since the days of Languis, have been studied with care, and the characters which they furnish have been employed, both in artificial and natural arrangements, in the construction of the primary divisions. It would have been of some advantage to the science, had conchologists ascertained the use of the teeth in the economy of the animal, before forming any divisions from their presence, absence, or position. They do not appear to be the index of any peculiar organization, neither can they be employed to bring together naturally allied families. The use of the adductor muscle is to close the shell; the ligament opens it; and the teeth of the hinge seem destined to modify and direct these movements. The characters furnished by these three parts of the shell appear to be nearly of equal importance, and fit only to occupy a very subordinate place. Were the circumstances connected with the teeth of the hinge to become the foundation of the higher divisions, many natural families would be broken. Thus, the genus anodonta would be removed from the unio, although they are both fluviatile, possess one long subulated foot, one syphon in the form of a hole, the summit of the cloak furnished with cirri, the branchiæ in part re-united, viviparous, carrying the young in the branchiæ. In short, it seems to be a character fit only for generic and specific distinctions.

Bivalve shells have often been divided into equilateral and inequilateral. These differences do not appear to be the signs of any peculiar character of the animal, or any of its functions. They must influence, to a certain extent, the relation between the different parts, but this influence is not sufficiently obvious. The character thus furnished is of an uncertain kind. It is influenced by the age of the individual, and therefore can only be employed with caution in specific distinctions.

The last character of the bivalves which we shall notice is the power which some of them possess of piercing stones and wood for the purpose of forming to themselves a retreat. These are termed *borers*. It was supposed by many that the animal secreted a liquor with which it dissolved the bodies into which it penetrated, but the sagacious Reaumur soon ascertained that the boring was performed by means of a rotatory movement of the larger valves. M. Fleuriel-Bellevue states, that the calcareous stone in which the *rupellaria lithophaga* is found, is often discoloured in the immediate neighbourhood of its recess. This may arise from other secretions of the animal, or even from the stagnant sea water in the hole, and not from the action of the phosphoric acid, or any other solvent supposed to be employed by the animal. These would act equally on the shell as on the calcareous rock. But the borers are not confined to calcareous rocks, they also lodge in slate-clay, and other argillaceous strata. This is very often the case with the *Pholades*. But this character can never be extensively employed, as the same species which, at one time, may be found imbedded in stone, will be observed at another seated among the roots of sea-weed, or buried among gravel.

From the preceding remarks it will appear obvious, that there are many characters furnished by the shell, which give us indications of corresponding peculiarities in the structure of the animal, and on that account ought to be employed in every natural arrangement. These characters have this circumstance to recommend them, that they are obvious and permanent. The objects which furnish them can be preserved in our cabinets, and serve to perpetuate our recollection of the appearances which the more perishable parts have exhibited.

There is yet another class of characters to be considered, very variously rated by different authors. These characters are taken from the situation in which shells are found, whether on the land, in fresh water, or in the sea.

This mode of dividing testaceous bodies has not been

Mollusca. sufficiently attended to by conchologists, who have, in general, condemned the plan, as founded upon an improper principle, viz., the classification of animals from the places which they frequent, instead of the forms which they exhibit. Such a mode of arranging the higher divisions of the different classes we would readily censure; but when employed in the inferior subdivisions of the testacea, we regard it as an important and a natural character. We ask the true naturalist to say, which is the most important character, the hinge having teeth or wanting projections, and the animal residing in fresh water or in the sea? We anticipate with confidence the preference which would be given to the latter, although the decision might provoke a sneer in a mere collector. Nature has evidently drawn a line of separation between the three tribes, which it is not difficult to perceive.

The terrestrial testacea are destined to live on vegetable matter. Their organs of respiration are suited to the medium in which they reside. Their organs of feeling are, in general, more numerous than those of the fluviatile or marine shells. The tentacula of the latter seldom exceed two, while in the land shells the tentacula are, in general, four in number. The eyes are likewise differently placed; in the aquatic testacea they are situated on the head, at the base of the tentacula; whereas the eyes in nearly all the terrestrial species are placed on the tip of these organs. We might also add, that no bivalve shells are found on the land; they belong exclusively to fresh water and to the sea.

The fluviatile shells, though destined to reside in a different medium from the terrestrial, have in the greater number of genera their organs of respiration (according to Cuvier) nearly the same, and are, therefore, compelled to come occasionally to the surface to respire. They have usually two flat tentacula, with the eyes placed at the base. They may, in general, be distinguished from the marine kinds by the superior thickness of their epidermes, their corneous colour, and semi-transparency.

The marine shells are the most numerous, the most beautiful, and the most highly prized of all the testacea. Many of the univalves of this tribe possess a lengthened respiratory tube, with a canal in the shell for its protection, a circumstance not observed in the fluviatile testacea. There is one circumstance which at once points out the difference in structure between the fluviatile and marine testacea: the fluviatile cannot live in salt water, nor the marine in fresh water. This fact points out an arrangement in their organization to which conchologists ought to pay attention.

These remarks are calculated to persuade conchologists to attend to the character furnished by the habitation of shells. In the formation of genera, it ought to be respected; in the higher divisions it would be inconvenient. The carelessness of Linnæus with regard to this character, is the principal reason why his genus *helix* is such a confused and indigested mass. Were the distinction arising from habitation to be observed in the distribution of the testacea, no confusion could possibly take place. Some changes might be occasioned by it, but much practical difficulty would be avoided. Indeed, so useful is the distinction, that conchologists, without avowing the propriety of the principle, have in many instances observed it.

Having thus taken a short view of the different characters employed by conchologists in the arrangement of the testacea, and endeavoured to ascertain their relative importance, we shall conclude this part of the article by an application of the principles we have established, to an examination of the Linnæan genera, and to an enumeration of those genera which subsequent naturalists have formed, without, however, attempting to give even an approximation to many of the modern divisions, which have been multiplied beyond all bounds; as our present object is to convey to the reader some farther remarks, illustrative of the history of the science, rather than specific descriptions.

LINNÆAN GENERA.

Mollusca.

1. *CHITON*.—The only change which has taken place in this genus, of any consequence, is its transference to the naked cephalous mollusca, effected by Lamarck. The inhabitants bear a near resemblance to those of the genus *patella*, and belong to the order cyclobranchia of Cuvier. The marginal ligament which connects the testaceous plates, even after the extraction of the animal, is, in fact, the margin of its cloak, and offers, in connection with the notches of the plates, more certain and convenient distinctions for the distribution of the species, than the number or appearance of the valves, a character exclusively employed by Linnæus.

2. *LEPAS*.—This genus has undergone several important alterations since the days of Linnæus. As originally constructed by that author, it contained shells which differ widely from one another in habit and form. Bruguière, the celebrated French conchologist, separated the fixed shells furnished with an operculum, under the name of *Balanus*, and those which were seated on a peduncle, he retained under the generic name *Anatifer*. He thus suppressed entirely the Linnæan name of the genus. To the name of his first genus, we have no objections, but the second, though it records a curious fact in the history of popular errors, has been injudiciously selected. The name *Lepas* has been retained by the best British writers, who have described seven species which live in our seas. These are distributed into two sections, according as the valves are five or more in number. The *Lepas anatifera* is an example of the first division, and the *L. scalpellum* of the second.

The genus *balanus*, as thus formed by Bruguière, and represented by the *lepas balanus* of Linnæus, contained nineteen species. From these Lamarck has separated the *B. diadema*, *testudinaria*, and *balanaria*, to form his genus *Coronula*. These shells are conical, and have the compartments formed into twelve areas, six of these being depressed, and six elevated. They chiefly inhabit the skin of the whale, the base of the shell being placed in the fat. Lamarck has likewise formed another genus, from two species analogous to the *coronulæ*, which he terms *Tubicinella*, and characterises it thus:—"Testa univalvis, regularis, non spiralis, tubulosa, versus basin attenuata, utriusque truncata; apertura orbiculata terminali; operculo quadrivalvi." The *lepas striata* of Pennant is now the representation of a new genus termed *Creusia*.

M. Dufresne (*Annales du Museum*, vol. i. p. 465), endeavours to prove by very inconclusive reasoning, that these shells are formed posterior to the birth of the animal. He supposes that, when they become too small to contain the inhabitants on account of their increasing size, the old shells are forsaken, and more commodious dwellings formed, until the animal reaches its full size. Other proof, however, than what the author adduces, is necessary to render the opinion probable.

Lamarck, in his *Système des Animaux sans vertèbres*, placed these shells in a separate section at the end of the bivalves, and among the acephalous mollusca. Afterwards he considered them as constituting a particular division of the crustaceous animals; and, lastly, he has assigned them a place in his new class, which he terms *CIRRHIPIDES*.

3. *PHOLAS*.—This very natural genus was placed among the multivalves by Linnæus, in the twelfth edition of his system. It is now united with the bivalves, the accessory plates at the hinge being regarded as of subordinate importance. In other respects it has stood the test of modern innovation, with the exception of the genus *GASTROCHENA* of Spengler, in which the teeth are obsolete. This includes the *pholas* hians of Chemnitz, and the *mya dubia* of Pennant.

4. *MYA*.—If we consider as definite the character assigned to this genus by Linnæus himself, we shall find that it excludes many species which differ from the *M. truncata*,

Mollusca at present considered as the type of the genus. In this shell, the valves gape at both extremities, the ligament is internal, and placed on a thick erect tooth in one valve, not inserted into the opposite side. As the *M. vulsella* of Linnæus is close at both ends, and destitute of a tooth, it has been separated from the true myæ, and formed into a distinct genus by Lamark, under the title *VULSELLA*. This shell presented some difficulty to Linnæus, as he placed it at first among the *Pinnæ*, and afterwards among the *Myæ*. Even Bruguière gave it a place among the oysters.

Another genus has been formed by Lamark from the mya siliqua of Chemn. (*Conch.* vol. xi. p. 192, tab. 198, fig. 1934). He calls it *GLYCIMERIS*. Though nearly related to the true myæ, by gaping at both extremities, yet it differs from them in the hinge, which is destitute of teeth, and in the ligament being external.

A new genus was formed by M. M. Groye, (*Annales du Museum*, vol. ix.), which he terms *PANOPEA*, and assigns to it the following characters:—"Coquille transverse, bail-lante inégalement au deux bouts, charnière semblable dans l'une et dans l'autre valve, ayant une callosité ou grosse dent allongée, placée en avant et sur le corselet; decurrente sur le bord intérieur, relevée en arête, mousse et saillant postérieurement; une dent cardinale conique un peu comprimée et arquée, et sur le valve droit une fossette dans laquelle s'en-grène la dent de la valve opposée; ligament extérieur, cro-chets peu protuberans, corselet large, deux impressions musculaires dans chaque valve situées vers les extrémités." The type of this genus is the mya glycimeris of Gmelin first noticed by Aldrovandus. It is inserted among the British shells by Mr. Donovan upon very slight authority. In the construction of the genus, we think, that M. Groye has acted properly, but there was no necessity surely for changing the trivial name (of the first described species) bestowed upon it by the discoverer. He has added another species from Monte Pulgnasco in Parma. In the trivial name of this species, we consider that he has been guilty of an act of injustice. He has called it *P. Faujas*, in honour of Faujas St. Fond, the zealous Professor of Geology in the Museum of Natural History at Paris. But the truth is, that it was found by M. Cortezi, Counsellor at Parma, and a successful investigator of the organic remains of that district. It ought, therefore, to have obtained the name of *P. Cortezi*, in honour of the discoverer, instead of the name of Faujas St. Fond, who received it from M. Cortezi, and whose sole merit in the subject consisted in his bringing it in safety to Paris.

The principal error of Linnæus in the construction of this genus, consisted in the insertion of fluviatile shells among his marine species. Bruguière readily perceived this error, and formed a new genus for their reception, which he called *UNIO*. But this group, now denominated *NAYADES* by Lamark, includes the genera *unio hyria*, *anadonta tridina*, and, we may add, *alasmodon*.

5. *SOLENS*.—This genus has undergone few changes since the days of Linnæus. The character has been somewhat restricted, and those species have been removed, in which the external margin is a little arcuated, and the cardinal teeth articulated, and two in number, and formed by Lamark into a new genus, which he terms *SANGUINOLARIA*. The animals of this genus, according to Poli, differ from the solens, in having the tubes of the syphon separate, and of unequal length and thickness. The *S. minutus* of Linnæus, found in our seas, is referred to the genus *HIATELLA* by Cuvier, a genus very imperfectly defined, but nearly allied to, if it be not identical with, the byssomia of the same author, which includes the *mytilus rugosus* of Linnæus.

6. *TELLINA*.—This extensive genus of Linnæus, the essential character of which is to have an anterior inflection or fold in each valve, and lateral teeth, includes many shells

which differ greatly in form and habit, and which disagree even with his own definition. Hence several important improvements have taken place in the distribution of the species.

The first change in the genus of any consequence consisted in the separation of the fluviatile from the marine species. This was accomplished by Scopoli, (*Introd. ad Hist. Nat.* 397), who bestowed on them the generic name of *Sphærium*. Bruguière afterwards wantonly changed the name to *CYCLAS*, and this change has been embraced by Lamark and other naturalists.

Another new genus of fluviatile shells, allied to the preceding, has been formed by Bruguière and Lamark for the reception of one species. The genus is termed *GALATHEA*, and the species *G. radiata*. There are two approaching hinge-teeth in the right valve, with a cavity in front, and two distant hinge-teeth in the left, with an intermediate large grooved callosity. The lateral teeth are of considerable size. The ligament is external, and the muscular impressions are two in number, and lateral.

The *Tellina inæquivalvis* presents characters which readily distinguish it from the other species with which Linnæus placed it. The shell is inequivalve and inequilateral; the ligament is internal, and the lateral laminae are wanting. Besides, the animal differs from the other inhabitants of the tellinæ, and is nearly related to the solens. Hence Bruguière formed a new genus for its reception, which he termed *PANDORA*.

There are several species of the genus tellina and Venus, which Bruguière and Lamark have formed into a separate genus called *LUCINA*, which is thus characterised:—"Testa bivalvis, æquivalvis, orbiculata, vel ovato transversa; nati-bus arcuatis, postice versis. Cardo dentibus cardinalibus 1. s. 2. variabilibus; lateralibus 1. s. 2. remotis, interdum subnullis." To this genus Lamark brings the *Tellina lactea* and *divaricata* of Linnæus, and the *muricata* of Chemn. (*Conch.* vol. xi. p. 209, tab. 199, fig. 1945-6), together with the Venus *fimbriata*, and *Pensylvanica* of Linnæus, and the *Jamaicensis* of Chemn. (*Conch.* vol. vii. p. 24, tab. 39, fig. 403-9). Cuvier, however, has restored the *T. lactea* to the genus *Loripes*, which Poli instituted for its reception.

7. *CARDIUM*.—This is, perhaps, the best constructed genus which Linnæus formed. The characters are definite and obvious, and all the species are naturally allied. Hence few changes have taken place in their arrangement. The animal constitutes a new genus in the system of Poli, which he terms *cerastis*.

Cuvier is disposed to constitute a new genus under the title *HEMICARDIA*, for the reception of the *C. cardissa* of Chemn., commonly called the Venus-heart cockle. The truncated appearance on the one side, and its being carinated in the middle, point out a conformation of the inhabitant different from the true cockles. Of this new genus we possess some fossil species.

8. *MACTRA*.—The ligament, in the marine bivalves, is, in general, placed on the outside, but in this genus, of which Lamark has formed his family *mactreacea*, the ligament is internal, and inserted in a cavity at the hinge formed for its reception. This family, as it stands at present, contains several well characterised genera.

In the restricted genus, *MACTRA*, as represented by the *M. stultorum* of Linnæus; the shell gapes a little, and the lateral teeth are strong, and lock into each other. The shells with age arrive at a considerable thickness. The inhabitant belongs to the genus *callista* in the system of Poli.

The genus *CRASSATELLA* of Lamark contains shells which close exactly, and have the lateral teeth obsolete. He describes seven fossil species, and eleven recent ones, viz. *mactra glabrata*, (*Encyclopédie Méth.* tab. 257. fig. 3); *venus divaricata* of Martini, (*Conch.* vi. p. 318. tab. 30. fig. 317, 318,) under the title *Crassatella contraria*; and the

Mollusca. following new species, *rostrata*, *Kingicola* (from King's Island!) *donacina*, *sulcata*, *subradiata*, *erycina*, *cycladea*, and *strata*.

The genus *ERYCINA* is composed entirely of fossil species. Lamarck has assigned it the following character: "Testa bivalvis, equivalvis, inequilatera, transversa. Dentes cardinales bini, superne divergentes, cum foveola minima intermedia: laterales compressi oblongi. Ligamentum foveola cardinali insertum." From the situation of the ligament being inserted in the small space between the teeth, the pit or cavity is less than in any of the other genera. The muscular impressions are two in number.

The transverse mactræ, which gape, but are destitute of lateral teeth, such as the *M. lutraria* of Linnæus, compose the genus *LUTRARIA* of Lamarck. The species already mentioned, and the *mya oblonga* of Gmelin, or mactra *hians* of Montagu, occur on our coasts; the former in great abundance at the mouths of the European rivers.

The genus *UNGULINA*, formed by Daudin, contains only one species, existing in the cabinet of Favanne. It is uncertain from what country it came. It is a regular longitudinal shell. The hinge is formed by one small tooth between two oblique pits. The muscular impressions are two in number. It is figured in Deterville's edition of Buffon. (*Hist. Nat. des Coquil.* tom. xx. f. 2, 3.)

Another genus established by the same author, and termed *ERODONA*, is subtransverse, irregular, and gaping, the hinge, in one valve, consisting of one hollowed tooth, and in the other a depression between two eminences. It includes two shells from the cabinet of Favanne. It is intermediate between the mactræ and myæ.

9. *DONAX*. The shells of this genus are readily known at first sight by their singular cuneiform shape. The hinge teeth are two in number, and the lateral teeth are spreading. The ligament is external, and, like the tellinæ, it is placed on the shortest side. This is a circumstance of rare occurrence among the inequivalve testacea. The animal belongs to the genus *peronæa* of Poli.

Lamarck has instituted a genus nearly allied to the preceding, termed *PETRICOLA*, the shells of which gape a little at both ends. There is one hinge tooth in one valve, and a bifid one in the other. The ligament is external; the muscular impressions are two in number; the structure of the hinge teeth, and the absence of the lateral teeth, at once distinguish this genus from the *donax* and *venus*. These animals are likewise peculiar in their habits. Lamarck quotes the *venus lithophaga* of Retzius, *Act. Acad. Tour.* vol. iii. p. 11, and the *venus lapicida* of Chemn. *Conch.* x. p. 356. tab. 172, f. 1664-5. But Lamarck's genus has been again altered by Fleurieu-Bellevue, who has formed his genus *RUPELLARIA*, from the *V. lithophagus* of Retzius, and another species termed *striata*. (*Mem. de l'Acad. de la Rochelle*, ii. tab. 2, fig. 9.) In this genus the shell is transverse and inequilateral, compressed in the anterior part, and swollen behind. There are two crooked hinge teeth on each valve, one simple, the other bifid. The ligament is external, and there are two muscular impressions. The *donax irio* belongs to this genus. The same author has formed two other genera of borers. The first he terms *RUPICOLA*, having a transverse inequilateral shell, a little gaping at the ends; no teeth or callosities. In an internal projection of each valve, there is a pit for the ligament. The other genus is named *SAXICAVA*. It is transverse, inequilateral, and gaping, without teeth or callosity, or pit. The ligament is external.

10. *VENUS*. This Linnæan genus contains so many species, that there is considerable difficulty in studying it. The formation of new genera, from its members, by diminishing their numbers, must prove highly acceptable to the student of conchology. Lamarck has succeeded so far by

previously restricting the character of the original as follows: "Testa bivalvis æquivalvis, binæquilatera transversa vel suborbicularis. Dentes cardinales tres in utroque valva, ad nates basi convergentibus. Ligamentum externum, nymphas labiaque obtegens." The three diverging hinge teeth constitute the essential character of the genus, so that Lamarck has been able to form three other genera from different characters.

The genus *CYTHEREA* (the meretrix of Lamarck's *Système des Animaux*) is thus characterised: "Cardo dentibus duobus tribusve approximatis, basi convergentes; uno solitario remotiuscula sub ano." It must be confessed that the insulated teeth under the lunule, in the absence of other characters, is obviously artificial. This genus contains many species requiring subdivision.

The genus *VENERICARDIA*, formed for the reception of some fossil species, is thus defined: "Testa bivalvis, æquivalvis, inæquilatera, extus longitudinaliter costata. Dentes cordinales sub-bini crassi oblique secundi." The number of hinge teeth, and the longitudinal ribs, readily distinguish it from the genus *Venus*. It is very limited in recent species.

Another genus instituted by Lamarck, and termed by him *CAPSA*, has two teeth in one valve, and a bifid tooth in the other, the type of which he considered to be the *donax lavigata* of Gmelin.

It was in the construction of the characters of the genus *Venus* that Linnæus unfortunately indulged in obscene allusions. It is now time that the pages of natural history were freed from such pollution. Other names, more expressive, can easily be substituted, alike advantageous to the interests of science, and the reputation of the illustrious Swede.

11. *SPONDYLUS*.—The shells which Linnæus included under this head are usually denominated prickly oysters. The genus represented by the *S. gæderopus* of Linnæus. The *S. plicatula* of the same author has been separated from the spondyli, and placed in a new genus, under the name *PLICATULA*. This genus differs from the former in the valves wanting ears, and in the absence of the triangular unisulcated space at the teeth of the under valve, so characteristic of the parent genus.

12. *CHAMA*.—This is by no means a well constituted genus in the Linnæan system, as it includes shells possessing very different characters. It has, accordingly, undergone several important alterations. Bruguière proceeded so far by establishing two new genera, and Lamarck, following the same plan, has added three more to the number. Those shells, which now belong to the genus *CHAMA*, are irregular, inequivalve, and adhere to other bodies. The hinge contains only one thick oblique tooth. It is represented by the *chama Lazarus* of Linnæus.

The genus *CARDITA*, of Bruguière, represented by the *C. variegata*, (Lister, tab. 344, fig. 84,) consists of equivalve free shells, with the hinge furnished with two unequal teeth, the one situated under the beak, the other lateral, under the anterior margin.

The *chama cor* of Linnæus appeared to Lamarck possessed of sufficient characters to constitute a distinct genus, which he has named *ISOCARDIA*. It is an equivalve, free, regular, heart-shaped shell, with two cardinal teeth, and a separate lateral one, with separate, diverging, involuted beaks. It is an inhabitant of the British Seas.

To Bruguière we owe the institution of the genus *TRIDACNA*, which is represented by the *chama gigas* of Linnæus, the largest shell in nature. The shell is equivalve and free. The hinge consists of two compressed teeth, and there is a gape at the lunule.

From the preceding genus of Bruguière, Lamarck has separated the *chama hippopus* of Linnæus, and formed from

Mollusca. it a new genus, which he calls *hippopus*. In its hinge it resembles the tridacna, but differs in the structure of the lunule, which in this is closed.

The genus DICERAS of Lamark, which he formed from the chama bicornis of Bruguière, approaches the isocardia in appearance, but the following character which he assigns, is fully sufficient for their discrimination: "Testa bivalvis inæquivalvis, adherens: natibus conicis, maximis, divergentibus, in spiram irregularem contortis. Dens cardinalis maximus, crassus, concavus, auricularis in valvula majore. Impressiones duo musculares." It occurs only in a fossil state.

Before dismissing this Linnæan division of shells, we must notice another genus which has been added to it by Lamark, from species brought from the Indian Seas. He terms it *etheria*, and originally described its generic character in the following words: "Coquille bivalve, inequivalve, irregulière, adhérente, a crochets court, enfonce dans la base des valves et derigées de cote. Charnière sans dent; deux impressions musculaires séparées et laterales. Ligament demi-interieur, enveloppant une callosité oblongée, et sortant en dehors par une fissure recourbée." He has described four species which are very rugged on the outside, but finely nacreous within, and has placed the genus in his family *camacea*, while in external aspect, and in the absence of teeth, the species make a near approach to the *ostrea*.

13. ARCA. Linnæus assimilated, under this genus, every shell the hinge of which presented numerous mutually inserted teeth. The shells which were thus united, have numerous relations, and constitute a very natural family. But in this family there are several groups of which Bruguière formed sections and Lamark genera. The genus arca is now restricted to those shells in which the hinge is in a straight line, and composed of numerous small lamelliform teeth, without lateral ribs. They have obtained their name from their resemblance to a ship, when the shell is inverted. Many species of this genus gape a little at the superior margin, to enable the animal to send out those tendinous threads by which it adheres to the rocks. The *A. lactea*, *noæ*, *tetragona*, *barbata*, and *fusca*, are natives of the British Seas.

The Linnæan arcæ, which have the hinge line broken and angular, belong to the genus NUCULA. In this genus the beaks are contiguous and turned a little backwards. The *nucula*, *nuclea*, *minuta*, *rostrata*, and *tenuis*, are found on our shores.

In the genus PECTUNCULUS, the hinge teeth are situated on a curved line, the shell is nearly orbicular, and the muscular impressions, which are two in number, form each a callous projection with a sharp margin. The arca pilosa, a native of Britain, is referable to this genus.

In the genus CUCULLÆA, the teeth of the hinge are similar to the arcæ, but at each extremity there are three or four transverse parallel ribs. It is represented by the arca cucullata of Chemn. (*Conch.* vii. p. 174. tab. 55. f. 526-528.)

To the family arcacea, Lamark, at one period, added the genus which he terms TRIGONIA. The hinge teeth are only two in number, diverging and compressed, but they are transversely grooved on each side. The muscular impressions are two in number in the recent species, *T. pectinata*, but in some of the fossil shells referred to in this genus, Mr. Sowerby could observe only one. The trigonia now forms along with castalia, the small family of Trigonées formed by Lamark at the suggestion of M. Valenciennes.

14. OSTREA.—Linnæus, in the construction of this genus, brought together many shells totally dissimilar in form, character, and habit, and hence it has undergone great alterations in the hands of succeeding conchologists. To associate in one genus shells which remain immovably fixed to the rocks and stones from their birth, and which exhibit few other signs of vitality than the opening and shutting of their valves, with those which possess a locomotive power;

to unite such as are irregular in their form and imbricated in their structure, with such as are of regular growth and solid texture, might surely be regarded as a violation of all the laws of a natural or an artificial system. Yet of such incongruous materials is the Linnæan genus ostrea composed, which, in spite of all its imperfections, has still its admirers in this country. (See *Descriptive Catalogue*, *Lin. Trans.*) The first important improvement in the reformation of the genus, consisted in the separation of the *pectens*, which was executed by Pennant, and afterwards by Bruguière and Lamark. Since new characters have been assigned to the genus ostrea, other separations must take place. It is thus defined: "Testa bivalvis inæquivalvis, rudis adhærens; cardine edentulo. Fossula cardinalis majoris valvæ ætate crescens. Ligamentum semi-internum. Impressio muscularis unica." The genus may be divided into two sections; the first having the margin of the valves simple, as the common oyster; and in the second the margins are plaited, as in the *O. crista-galli*.

In consequence of this change in the generic character, the ostrea malleus of Linnæus, (*Lister*, tab. 219, f. 54.) has been formed into the genus MALLEUS. The shell is free, gapes a little at the beaks, produces a byssus, has no teeth in the hinge but a conical pit for the insertion of the ligament, placed obliquely on the margin of each valve. It was for a long time highly prized by collectors.

The genus PECTEN is one of the best characterised, most natural, and most beautiful, in the system. The shell is inequivalve and regular, the hinge is destitute of teeth, and the internal ligament is fixed to a triangular cardinal cavity. There are fourteen species natives of our shores.

From the ostrea perna, ephippium, and isogonum, Bruguière formed the genus PERNA. The hinge is linear, and cut into a number of lengthened parallel veins, which receive the ligament. The interstices are formed into teeth, which simply oppose those of the other valve. In the anterior side of the valve, near the beaks, there is a callosity, and an opening for the byssus of the animal.

Lamark has constituted another genus, nearly allied to the perna, which he styles CREMATULA. The hinge in this genus presents only a row of pits for the ligament, which makes it appear crenulated. The intermediate spaces are not formed into teeth, neither is there any callosity, or opening for the byssus. He has figured two new species, which he terms *avicularis* and *mytiloides*, and a third is the ostrea picta of Gmelin, (*Chemn. Conch.* vii. p. 243. tab. 38. f. 575.)

Nearly related to the pectens is the genus LIMA of Bruguière. The species differ, however, in the ligament being in a great measure on the outside. They are all of a white colour. The ostrea lima is considered as the type of the genus.

The genus PEDUM of Bruguière differs from the preceding in the ligament being external, and attached to a long straight fissure. The ostrea spondiloidea of Chemn. (*Conch.* viii. t. 72. fig. 669, 670,) is considered as the type of the genus.

To this family we must add two genera, possessed of very singular characters. They have neither hinge nor ligament. The first, instituted by the celebrated botanist, Commerson, is termed ACARDO. The valves are depressed and nearly equal, and held together by the adductor muscle. The species at present known come from the eastern coast of Africa. The second is termed radiolites, and was instituted by Lamark. It differs from the former in the form of the valves, the inferior being turbinated, and the superior convex or conical. The species occur only in a fossil state, and have been long known to geognosts under the title ostracites.

15. ANOMIA. In the Linnæan system, this genus is equally faulty as the last. It contains many species, which

Mollusca. differ greatly from one another and from the generic character. Some are found recent on our shores, while others occur only in a fossil state. Lamark, having rectified the Linnæan character of the genus, has separated many species, now grouped, into distinct genera. In the restricted genus ANOMIA, the under valve has a hole or groove near the beak, which is closed by a testaceous operculum. This appendage is fixed to rocks or stones, and has a ligament attached to it.

In the genus CRANIA, represented by the *Anomia cranolaris* of Linnæus, the under valve is pierced by three holes, which are oblique and unequal. The genus GRYPHÆA was constituted from the *Anomia Gryphus* of Linnæus. The inferior valve is concave, terminating in a spirally involuted beak, projecting upwards; the upper valve is small, and resembles a lid. A transversely striated pit at the hinge contains the ligament. The only recent species known is called *G. angulata*. Many species are found in a fossil state in the rocks of this country.

Among the Anomia, Linnæus placed the shells which compose the genus TEREBRATULA, the characters of which are so obvious and distinct. In this genus, which is inequivalve and regular, the beak of the larger valve is produced, and pierced with a hole, through which the ligament of adhesion passes. From the great extent of this genus in fossil species, several subdivisions have been proposed.

From the Anomia placenta of Linnæus, Lamark has formed his genus PLACUNA. The hinge is remarkable for two teeth on the one valve, placed like the letter V, the base toward the beak, and two impressions on the other valve. It occurs in the Indian Seas. The natives polish it for ornaments.

To Lamark we are also indebted for having formed the genus CALCEOLA from the anomia *sandalum* of Linnæus. The largest valve is sandal-shaped, and has at the hinge two or three small teeth. The other valve is small, flat, semi-orbicular, and resembles an operculum. It is frequent in a fossil state in Germany.

Mr. Sowerby, in his valuable work on *British Mineral Conchology*, has made us acquainted with several new genera of fossil shells, which, by the older naturalists, would have been inserted in the genus Anomia. The genus PENTAMERUS is an equal-sided inequivalve bivalve, with one valve, divided by a longitudinal internal septum into two parts, the other by two septa into three parts or valves. Beaks incurved, imperforate. He has figured three species of this curious genus.

The genus PLAGIOSTOMA of Sowerby, is represented by the Pectenites *Plagiostomus* of Luid, (tab. 10, f. 639,) and is thus defined: "An oblique eared bivalve, hinge destitute of teeth or internal pit. Line of the hinge straight in one valve, in the other deeply cut by an angular sinus." He gives figures of two species in his first volume, the *gigantea* and the *spinosa*; and many others have been subsequently detected.

The genus DIANCHORA is nearly related to the preceding, but in this the shell is fixed, and the attached valve has an opening in place of a beak. The other valve is beaked and eared.

The anomia *spinosa* of Linnæus probably belongs to Mr. Sowerby's genus PRODUCTUS, which he thus defines: "An equilateral unequal-valved bivalve, with a reflexed, more or less cylindrical margin; hinge transverse, linear; beak imperforate; one valve convex, the other flat or concave externally." But many new genera must be instituted, to embrace all the fossil species which would have been referred by Linnæus to the genus Anomia.

16. MYTILUS. Before proceeding to notice those new genera which have been formed from the Linnæan mytili, we may state, that the three parasitical species of the *Systema Naturæ*, belong to the genus Ostrea, to which they

have been transferred by late authors. But improvements of a more important kind have been effected. Linnæus had associated together in this genus both fluviatile and marine shells. The former now constitute a very natural genus termed ANODONTA, formerly referred to, of which the British rivers furnish several species. The muscular impressions are three in number.

It was easy to perceive that the mytilus hirundo of Linnæus did not belong to the true mussels, it being an inequivalve shell. Accordingly Lamark has constituted a new genus for its reception, which he terms AVICULA. The mytilus *margaritiferus* of Linnæus is of this genus.

Lamark, by restricting the characters of the genus mytilus to include such species as have the beak terminal, has in this manner separated the transverse species to form the genus MODIOLA. The mytilus modiolus of Linnæus is the type of the genus. It is common on the British shores, together with the modiola *discors* and *discrepans*. We are at a loss to account for the scruples of Lamark (*Annales de Museuss*, vol. x.) about considering this genus as byssiferous. Had he ever examined the figure of the type of the genus in tab. 53 of *Zoologia Danica*, all his doubts would have been removed.

17. PINNA. No changes have taken place in this Linnæan genus, except that a few new species have been added.

In the course of our review of the Linnæan genera of bivalves, we have exposed some of those errors which the Swedish naturalist committed in associating discordant species under the same genus. Perhaps our examination of the univalves will make us better acquainted with the imperfections of that system, and dispose us to prize those improvements which subsequent naturalists have introduced.

18. ARGONAUTA. This genus, which contains but few species, is highly prized by collectors, who call the principal species by the name of paper nautilus. By restricting the characters of this genus, so as to embrace only those species in which the opening is interrupted by the involution of the spire, and in which the dorsal ridge is double, Lamark has been able to form the genus CARINARIA. In this the mouth is entire, and the dorsal ridge single. It is represented by the argonauta *vitrea* of Gmelin.

18. NAUTILUS. Since the days of Linnæus, our knowledge of the *multilocular* testacea has been greatly enlarged. He contented himself with arranging all the species with which he was acquainted under one genus, but, in consequence of modern industry, even the genera exceed the number of Linnæan species. Many recent species have been discovered by the aid of the microscope, among the sand on the sea shore, and a still greater number in a fossil state among the calcareous strata. These newly discovered kinds exhibit many different characters, and have compelled conchologists to institute so many new genera for their reception, that the genus Nautilus of Linnæus appears rather as the head of a family or order, than as a separate genus of univalve shells. In this department the names of Bruguière, Lamark, Montfort, Parkinson, and Sowerby, deserve respectful notice; and it is from their writings that the following remarks concerning the multilocular testacea have been extracted. The multilocular testacea may be divided into three sections; the first including those which are obviously spiral; the second, those which are produced; and the third, those which are of a globular or lenticular form. These sections are merely provisional, and are only intended to render more obvious and intelligible our notices of the genera.

1. *The spiral multilocular testacea.* At the head of this first division stands the modern genus NAUTILUS, in which the turns of the spire are contiguous, and the last whorl incloses the others. The partitions are perforated by a tube. We possess on our shores several species of this genus, of which the *N. crispus* is the most common.

Mollusca. In form, the genus *LENTICULINA* is nearly related to the former. The margin of the mouth reaches to the centre of the shell on both sides, and the partitions are destitute of a syphon. Lamark is in possession of a recent shell of this species from the sea near Teneriff.

The shells which Mr. Sowerby, in his *Mineral Conchology*, has figured under the genus *ELLIPSOLITHES*, have the whorls conspicuous, although the mouth clasps the body whorl. But it is easily distinguished from the other genera with which it is related by its elliptical form.

The genus *DISCORBIS* of Lamark (formerly called by him *Planulites*) bears a considerable resemblance to the nautilus in form, but the whorls are all apparent, and the partitions entire.

In the genus *ROTALIA*, the spires approach to a conical shape, and the marginated trigonal aperture is reflected towards the base of the shell. It consists of shells which are now found in a fossil state.

The nautilus spirula of Linnæus has afforded characters for the construction of a new genus termed *SPIRULA*. The whorls are separate, the mouth orbicular, the partitions perforated by a tube, and the last turn of the spire prolonged in a straight line. This last character was unknown to Linnæus, who had only seen the spiral body of the shell.

The genus *SPIROLINA* has the last turn of the spire produced like the preceding, but the whorls are contiguous. The partitions are perforated by a tube.

The genus *LITUOLA* is allied to the spirula and spirulina in the production of the last whorl. The spires of the body are contiguous, and the partitions are pierced by a number of holes.

In the preceding genera the inner walls of the cavity are simple; but in the two following, the walls are formed into joints by sinuous sutures. The first of these is the *AMMONITES*, including those shells which have been termed *cornua ammonis*. The origin of this name is, by some, sought for in their resemblance to the horns of a ram; by others, to their having been found near the temple of Jupiter Ammon in Upper Egypt. By the Indians, the *ammonites sacer* is considered as a metamorphosis of the god Vishnu, and termed by them *salgram* or *salgraman*. It is found among the pebbles of the Gandica where it joins the Ganges. In this genus the whorls are contiguous, spiral, depressed, and obvious.

The *ORBULITES* of Lamark differs from the ammonites in the circumstance of the last whorl embracing and concealing the others. In both the syphon is marginal.

Nearly allied to the preceding is the *TURRILITES* of Montfort. It is similar in internal structure, but while the shells of the former are spirally discoid, those of the present genus are spirally turreted, resembling a Turbo or Turricula. Several species are figured by Sowerby in his *Mineral Conchology*.

The genus *SCAPHITES*, formed by Parkinson, possesses very peculiar characters. It commences with a depressed volution, the last turn of which, after being enlarged and elongated, is diminished and reflected inwards.

2. *Multilocular testacea with the shell produced.* It must be confessed, that the genera of this section are but imperfectly understood. The recent kinds are too small to admit of any investigation of the animal, so that we are left entirely to conjecture.

The genus *HIPPURITES* is of a conical form, and either straight or crooked. Within it is transversely chambered, and furnished with two lateral, longitudinal, obtuse, converging ridges. The last chamber is closed by an operculum.

In the *ORTHOCERA* the shell is straight or slightly bent, and conical. The chambers are distinct, and pierced with a tube. We possess on our shores many minute species of this genus.

The genus *BACULITES* of Faujas St. Fond possesses a

structure similar to the ammonites, the inner walls being articulated with sinuous sutures, and the partitions perforated. The shell is fusiform or bent into two parallel limbs. Mr. Parkinson has contributed greatly to our knowledge of this genus, and has termed it *Hamites*. We prefer the name of the original discoverer to that of our English naturalist, which is very faulty. For, according to Pliny, "*Hammites ovis piscium similis est.*"

In the *BELEMNITES* the shell is straight, conical, pointed, solid at the summit, and furnished with a lateral gutter. There is seldom more than one of the cells apparent, of a conical form, the older ones having been effaced in succession. The genus *Tulaxodes* of Guettard is not, perhaps, entitled to be considered as distinct.

The *AMPLEXUS* of Sowerby belongs to this division. It is nearly cylindrical, divided into chambers by numerous transverse septa, which embrace each other with their reflected margins. It contains one species from the limestone rocks of Ireland, but we may add that it has been supposed to belong to the zoophytes rather than the mollusca.

3. *Multilocular testacea of a globular form.* The first genus of this section is the *MILIOLA*. The shell is composed of three or four oval cells, turning round an axis parallel to their longest diameter. Many recent species of this genus are common on our shores; they were included by Montagu in his genus *vermiculum*.

In the *RENULINA* the cells are narrow, linear, unilateral, curved into a part of a circle, and all situate on the same plane. The smallest cell forms a little arch round a marginal axis, and the others are placed contiguous to this on the same side. The species are all fossil.

The *GYROGONA* was for many years viewed as a shell of a spheroidal form, composed of linear, curved, grooved, pieces, terminating in two poles, the external surface obliquely spiral, the spires terminating at each pole, and as found only in a fossil state. But more recent observations have connected it with the seed vessel of the genus *chara*.

The shells of the genus *NUMMULITES* are remarkable for their lenticular form. The external surface is smooth, and the cells concealed, but internally the transverse shells are disposed in a spiral discoid form. The cells are imperforate; they are the camerinæ of Bruguière, the helecites of Guettard, and the discolithes of Fortis. This last author supposes, that they are formed in the interior of an animal analogous to the sepia. The same opinion may, with propriety, be entertained of many other genera of multilocular testacea. Faujas St. Fond found a recent specimen of a nummulite among the fragments of the corallina officinalis, brought from the island of Corsica.

It is probable that the genus *LAGENA*, formed from the serpulæ *lagenæ* of Walker's *Testacea minuta Rariora*, belongs to the multilocular testacea; as in some of the species we have observed the appearances of internal divisions.

As connected with this division of the Linnæan genera, we may take notice of the British shell called by Lightfoot *Nautilus lacustris*, (*Phil. Trans.* lxxvi. tab. 1). The very circumstance of its being a fresh water shell, distinguishes it sufficiently from all those which we have been considering, and its other characters are likewise peculiar. The partitions are distant, and consist of three testaceous plates, not united, which leave a sufficient opening between them to allow the animal to protrude and withdraw itself. It constitutes a distinct genus, which has been termed *SEGMENTINA*, from the trivial name bestowed on it by Solander, which refers to the structure of the septa. Its place in the system is next to the genus *planorbis*.

These genera of multilocular shells which we have enumerated, are those which have been established with the greatest attention. Many other genera might have been enumerated, particularly those formed by Montfort, but the character given of them by Cuvier will satisfy the curiosity

Mollusca. of the reader. When speaking of the *Conchyliologie Systématique* of that author, in reference to this subject, he says, "*Où presque toutes les espèces et même des variétés sont élevées en genres.*"

19. CONUS.—This genus is so very natural, that it has undergone no changes since the days of Linnæus, except by the addition of new species. That author was acquainted with thirty-five species and a few varieties; but M. Hawss communicated to Bruguière descriptions of one hundred and forty-six, from specimens existing in his own cabinet. We cannot boast of any British species.

20. CYPREA.—This genus is equally natural as the former. It has undergone no change since the days of Major.

21. BULLA.—This genus presents to the mere conchologist a source of great perplexity. It displays at once the absurdity of dividing the molluscous animals into testaceous and naked, since no such distinction is observable in nature. Many of the shells which were formerly included in this genus are found to be contained within the common integuments of the animal. It was this circumstance which induced Linnæus to separate the limax and the aplysia from the vermes testacea. Both of these have shells, but they are concealed. In imitation of the same principle, Lamarck has formed a new genus among the naked mollusca, called BULLÆA, for the reception of those bullæ in which the shell is concealed. The bulla *aperta* is the type of the genus. The bulla plumula of Montagu is another shell included in the animal, which is very closely connected with the genus *Pleurobranchia* of Cuvier. (*Annales du Mus.* v. 269). It may be asked, are all the other bullæ found in similar situations, and consequently do they belong to the naked mollusca? Lamarck considers, and apparently with reason, that all those which are distinctly spirally involuted, and ornamented with colours, are not entirely inclosed in the cloak of the animal, and ought therefore to be ranged with the testaceous mollusca. How few British species does this character include. As originally constituted, the genus of Linnæus contained species of very different characters, so that many new genera have been formed. To Bruguière, Lamarck, and Draparnaud, we owe all the improvements which have taken place.

The modern genus BULLA includes those shells which correspond with the following character:—"Testa univalvis, convoluta, ovato-gibbosa vel cylindracea: spira non exserta, apertura longitudine testæ, labro acuto." The *B. ampulla* is the type of the genus.

The genus OVULA, instituted by Bruguière, is more nearly related to the cyprea than to the bulla. It differs, however, from the former, in the left margin of the lip being smooth; and from the latter, in the edges of the mouth being rolled inwards, and in the shell being produced at both ends. The *B. ovum* of Linnæus is the type of the genus; the *B. patula* of Pennant.

The bulla terebellum has been employed by Lamarck to constitute his genus TEREPELLUM. The canal at the base of the mouth, and the truncated pillar, furnish the generic characters.

Linnæus was for some time uncertain where to place those shells which he at last inserted in the genus bulla, under the trivial names ficus and rapa. These, with a few of the *murices* of the same author, constitute the genus PYRULA of Lamarck. Its canaliculated base removes it from the bullæ, while the short spire, the swelling of the last whorl, the smooth pillar, and pyriform shape, distinguish it from all those with which it is apt to be confounded. It is more nearly allied to the Fusus than to any other.

The preceding genera consist of species which live in the sea. The *B. virginea* is a terrestrial shell, and ought to form a distinct genus next the bulinius. The *B. fontinalis*, *hypnorum*, and *rivalis*, reside in fresh water. They have, with much propriety, been formed into a distinct genus by

Draparnaud, which he calls PHYSA. They are all sinistral Mollusca, shells, and will require further division when the form of the animal shall become the basis of generic distinction. The *fontinalis* and *hypnorum* are natives of Britain.

In the genus ACHATINA of Lamarck, the pillar is truncated as in the terebellum, but the base of the mouth is entire. It is represented by the bulla achatina of Linnæus. To this genus we may refer the *Buccinum acicula* of Müller, which is found in England, and the *Helix octona* of Linnæus, erroneously considered as a native of Britain.

22. VOLUTA.—This genus, as originally formed by Linnæus, depended, as he informs us, on the plicæ of the pillar, "*volutæ genus facillime distinguitur columella plicata.*" But as this character belongs to many shells otherwise very different in form, succeeding conchologists have separated many species from the genus, and reduced it within more natural limits. As it now stands it is thus defined, "*Testa univalvis, ovata, subventricosa, apice papillari; basi emarginata. Columella plicata; plicis inferioribus, majoribus, vel longioribus.*" The type of the genus is the voluta musica.

Bruguière removed from the Linnæan genus those species which are destitute of a groove at the base of their mouth, and of which Lamarck formed the genera AURICULA, TORNATELLA, and VOLVARIA. In the latter the spire is not produced; in the former it is produced. To the genus auricula, which contains land-shells, the *V. auris-midæ* and *auris-judæ* belong. The *V. tornatilis* is the type of the genus tornatella. In his reference to the genus volvaria, Lamarck quotes the bulla cylindracea of Pennant and Da Costa, as if they were one and the same. But Pennant's shell is a true bulla, while that of Da Costa is regarded as the voluta pallida of Linnæus, and probably belongs to this genus.

In the genus OLIVA, the turns of the spire are separated externally by a very distinct gutter or canal, and the pillar is obliquely striated. The voluta oliva of Linnæus contains many different species of this genus, which are remarkable for the smoothness of their surface and the brilliancy of their colours.

The ANCILLA, which, like the former, is of a sub-cylindric form, is destitute of the groove which separates the whorls, and is characterised by an oblique callous ring at the base of the pillar.

In the genus MITRA of Lamarck, the spire is pointed instead of ending in a small knob, as in voluta, and the plicæ of the pillar increase in size from the base upwards, which is the reverse in that genus. The *V. episcopalis* of Linnæus is the type of this genus, which contains many species much sought after by collectors.

In the COLUMBELLA, the shell is oval, the spire short, and the inner edge of the right lip is swollen. The *V. mercatoria* is the type of the genus.

The MARGINELLA is very distinctly marked by the prominent callous collar which surrounds the outside of the right edge of the shell. The opening of the mouth at the base is scarcely grooved. The *V. glabella* is the type of the genus.

The CANCELLARIA is nearly related to the genus columbella, but the absence of the swelling of the lip, and the presence of the compressed sharp plicæ of the pillar, furnish sufficiently obvious characters of distinction. The *V. cancellata* of Linnæus is the type of the genus.

In the genus TURBINELLUS the shell is turbinated, sub-fusiform, and canaliculated at the base, having from three to five transverse compressed plicæ on the pillar. The *V. pyrum* is the type of the genus.

23. BUCCINUM.—This is another of the Linnæan genera of shells, which has undergone great alterations. As originally constructed, it embraced many distinct groups of shells, which Bruguière and Lamarck have since formed into genera. The restricted character of the genus Buccinum is

Mollusca. thus defined by the last mentioned author: "Testa univalvis, ovata vel elongata. Apertura oblonga, basi emarginata, nudata, canali nullo. Collumella convexa plana."

Bruguiere separated the genus *CASSIS*, in which the opening is oblong and denticulated on the right side, with a short canal towards the back of the shell. The right margin has a callous border. The *Buccinum cornutum* of Linnæus is the type of the species.

The genus *TEREBRA* was likewise formed by the same author. It is remarkable for its turreted form, the spire being at least twice as long as the mouth, and the pillar at the base twisted.

In the genus *NASSA* the groove in which the mouth terminates is reflected as in *Cassis*, but the left edge of the mouth is callous, and forms upon the pillar a transverse fold.

The *PURPURA* is readily distinguished from the *Buccinum* and *Murex*, with which it has often been associated by its naked compressed pillar, ending in a point at the base.

The genus *DOLIUM* is distinguished by its bellied forms and transverse rings, together with the margin on the right side being denticulated its whole length.

The genus *HARPA* is well known, and is distinguished by its sharp parallel longitudinal ribs. The pillar is smooth and pointed at the base.

In the genus *EBURNEA*, the shell is smooth, and the pillar umbilicated and subcanaliculated at the base. The *buccinum glabratum* is the type of the genus.

24. *STROMBUS*. This Linnæan genus is now converted into a family, distinguished by the right margin changing its form with age, and having towards the base an indenture or sinus. It contains four genera, *strombus*, *rostellaria*, *pterocera*, and *hippocrenis*.

In the genus *STROMBUS*, the canal is short, the right margin is simple, and ends in a sinus. The *S. pugilis* of Linnæus is the type of this genus.

In the *ROSTELLARIA* the canal is produced into a long beak, the right edge of the mouth is entire, and rests above on the spire, and is sometimes decurrent. The sinus is contiguous to the canal. The *R. cornuta* of Mart. (*Conch.* iv. tab. 158. f. 1495,) is the type of the species.

In the *PTEROCERA* the canal is also lengthened, but the right margin is dilated and digitated with a sinus near the base. The *strombus pes-pellicani* of our shores is of this genus.

25. *MUREX*. The modern genus of this name is thus defined by Lamark: "Testa univalvis, ovata vel oblonga; basi caniculata; suturis varicoso-tumidis, sub asperis, longitudinalibus, et persistentibus." In consequence of this restriction, the following genera, among others, have been instituted.

In the genus *FASCIOLARIA*, the spires are destitute of those longitudinal ribs which the murices always exhibit, while the pillar is furnished with two or three oblique folds. The *murex tulipa* of Linnæus is the type of this genus.

The shell of the genus *FUSUS* is lengthened, generally fusiform, destitute of longitudinal ribs, and bellied in the middle or lower part with a smooth pillar and lengthened canal. The *F. longicauda*, (Lister, tab. 918, f. 11. A.) is the type.

The *PLEUROTOMA* is distinguished from the preceding by a sinus or groove, which appears on the margin of the right edge of the mouth, near its summit. It is represented by the *M. Babylonicus* of Linnæus.

The genus *CLAVATULA* differs from the former, in possessing a short canal, and ought never to have been separated.

In the genus *CERITHIUM*, the mouth is oblique, terminating below in a short truncated or recurved canal, and having at the upper part a gutter more or less produced. The *Tympanotonos asper* of Mart. (*Conch.* 4. p. 314. Tab. 156. f. 1473,) is the type of the genus.

26. *TROCHUS*. This is a very natural genus in the Linnæan system, and has undergone few alterations in the hands of modern conchologists. The *T. perspectivus* has given rise to a new and very obvious genus, termed *SOLARIUM*, characterized by the internal spiral edge of the umbilicus being crenulated. Another species, the *T. labio*, is the type of the genus *MONODONTA*, which contains shells of an oval form, with a rounded mouth, furnished with a tooth, formed by the truncated projecting base of the pillar: the two margins are separated. The turreted trochi of Linnæus constitute the genus *PYRAMIDELLA*.

The *T. terrestris* of British writers is so imperfectly described and figured, that it is impossible to assign it a place in the system. It is nearly allied to the helix.

27. *TURBO*. This very extensive genus has been greatly dismembered by modern conchologists, in consequence of Lamark having restricted the character in the following terms: "Testa univalvis, conoidea vel subturrita. Apertura integra rotundata, edentula; marginibus superne semper disjunctis; columella basi planulata." Our *T. littoreus* is now considered as constituting the genus *LITTORINA*.

In the genus *SCALARIA*, the mouth is circular and bordered, with the margins united. The spires are covered with raised edged, slightly oblique, longitudinal ribs. The famous wentletrap is the type of the genus.

Lamark thus defines his genus *DELPHINULA*: "Testa univalvis subdiscoidea vel abbreviata conica, solida, margaritacea, umbilicata; anfractibus subasperis. Apertura rotundata, marginibus orbiculatim connexis." The *T. delphinus* is the type of the genus. There are many species of turbines common on our shores, which are excluded by the preceding characters from the genera *turbo* and *delphinula*, such as the *striatus*, *cingellus*, *bryereus* and others. They are distinctly turreted, with the margins of the mouth united, and constitute a genus termed *CINGULA*.

The *Turbo terebra* of Linnæus serves as the type of another genus, termed *TURRITELLA*, in which the margins of the mouth are disjoined, the spire regularly turreted, and the lip emarginated by a sinus. Nearly allied to the preceding is the genus *PHASIANELLA*, which Lamark thus defines: "Testa univalvis, ovata vel conica, solida. Apertura longitudinalis, ovata, integra; labro simplici acuto. Columella lævis basi attenuata. Operculum calcareum vel corneum animali adherens."

Perhaps a rigorous examination of the turbines of British writers might justify the formation of one or two new genera. In the genus *ODOSTOMIA*, the columella is furnished with a tooth. The *Turbo interstincta*, *unidentata*, *plicata*, *Sandvicensis* and *insculpta* of Montagu, are of this genus. They have no resemblance in their structure to the Linnæan *volutæ*; although they have been inconsiderately associated with them by the authors of the *Descriptive Catalogue*. The preceding genera are formed of marine shells; those that follow live on the land.

In the genus *CYCLOSTOMA*, the mouth is circular, with united, and often reflected margins. The animal is furnished with an operculum. The *T. elegans* of Montagu is the only British species of the genus.

The species which are related to the *Turbo bidens* *perversus* and *muscorum* of Linnæus, constitute a very natural family, which may be termed *PUPACEA*, distinguished by the mouth being furnished with teeth or testaceous laminae, and the last whorl nearly the same or less than the preceding. Perhaps the most convenient way of dividing them is into two sections, the first including the dextral, and the second the sinistral shells.

The dextral pupacea form two genera. The *PUPA*, as originally constructed by Lamark, was equally faulty with many of the old Linnæan genera. As it has been restricted to include dextral shells, with the animal possessing four tentacula, with eyes at the tips of the two longest, it can

Mollusca. embrace the *muscorum*, *sexdentatus*, *tridens*, and *juniperi* of Montagu. In the genus *CARYCHIUM*, formed by Muller, the tentacula are only two in number, with the eyes placed at the base. It is represented by the *T. carychium* of Montagu.

The sinistral pupacea form likewise two genera. The first, which is the *Clausilia* of Draparnaud, contains sinistral shells, with the animal furnished with four tentacula, with eyes at the tips of the two longest. This contains the following British species, viz. *bidens*, *perversa*, *biplicata*, *plicatula*, and *labiata*. The other genus, called *VERTIGO*, was formed by Muller. The animal possesses only two tentacula, with the eyes on their tips. The *T. vertigo* is the type of the genus.

28. *HELIX*. Linnæus, in constructing this genus, attended only to the character of the mouth being contracted or lunated, without regarding the habits of the animals, or even the other forms which the shells exhibited. Hence he has united globose, discoid, and turreted, terrestrial, fluviatile, and aquatic shells; animals with two and with four tentacula, with and without an operculum, oviparous and viviparous.

The marine species of Linnæus are few in number. The genus *JANTHINA* of Lamarck, has been formed from the *H. janthina* of Linn. a species of which has lately occurred at several places of the Irish coast. The opening is triangular, and there is an angular sinus at the right edge. The shell, which Linnæus terms *H. haliotoidea*, is completely concealed in the animal. There are many marine shells inserted in the genus *Helix* by British writers, which either belong to the restricted genus *Turbo*, or to the *Vermicularia*.

The further reduction of the Linnæan helices depends on the separation of the terrestrial from the fluviatile shells, and subdividing these according to the characters furnished by the different groups.

Among the terrestrial shells, the restricted genus *HELIX* is by far the most extensive. It contains those shells which are subglobose, with a convex spire; the opening entire, wider than long, and diminished in its upper part by the projection of the last turn but one of the spire. The animal is furnished with four tentacula, with eyes at the tips of the two longest. The *H. pomatia* is the type of the genus.

The genus *BULIMUS*, as originally constructed by Bruguière, was faulty in the extreme, but Lamarck has now modelled it so as to include those land shells which are turreted or conical, with the mouth larger than broad, and having, in general, the margin reflected with age. Like the *Helices*, they have no operculum, and possess four subulated tentacula.

From the *Helix succinea* of Muller (the *putris* of Montagu and Donovan, not of Linnæus) Draparnaud has formed the genus *SUCCINEA*. The mouth is large in proportion to the size of the shell, and effuse at the base with the outer lip thin, and the pillar attenuated. The *H. succinea*, although found in damp places, is not amphibious. It never enters the water voluntarily. Indeed, Muller says, "Sponte in aquam descendere nunquam vidi, a contra quoties eum aquæ immisi, confestim egrediebatur." The same remark is made by Montagu, and we have often witnessed its truth.

The *Helix pellucida* of Muller has been formed into a new genus by Daubebard, which he termed *Helico-limax*, but which Draparnaud, to avoid the use of a hybrid name, changed for the term *VITRINA*.

The fluviatile shells, included by Linnæus in his genus *Helix*, may, for the sake of present convenience, be considered as forming two sections, viz. those with and those without an operculum. To the former belongs the very

natural genus *LIMNEA*, containing conical or turreted shells; with the right lip joined to the left at the base, and folding back on the pillar. The *H. stagnalis* of Linnæus, is the type of the genus, of which we possess many British species. Two of these are truly amphibious, the *octona* and *fossaria*.

The genus *PLANORBIS*, instituted by Geoffroy or rather by Petiver, is remarkable for its discoid form, the spire revolving nearly in a horizontal line, so that all the whorls are obvious on both sides. Cuvier observed that the *P. cornea* was a sinistral shell, and it remains to be ascertained whether the whorls in the other species have a similar direction. We possess several British species of this genus.

The operculated divisions of fluviatile helices, is more numerous than the preceding, containing at least six genera.

The genus *VALVATA* was instituted by Muller to include depressed shells with an orbicular mouth, the animal, furnished with three tentacula and a plumose appendage, considered as the branchiæ. The *V. cristata* (*Helix crist.* of Montagu), and *piscinalis* (the *Turbo fontinalis* of Montagu,) are natives of this country.

The genus, now denominated *PALUDINA*, instituted by Geoffroy, and afterwards employed by Montfort, is represented by the *H. vivipara* of Linnæus. The shell is ovate or oblong, with a regularly elevated rounded spire. The aperture is entire, with the two lips united angularly at the summit. The type of the genus, together with *P. tentaculata* and *acuta*, are natives of Britain.

In the genus *AMPULLARIA* of Lamarck, the shell is globose, the base umbilicated, and the mouth longer than broad. The *H. ampullacea* is the type of the genus.

In the genus *HELICINA* of Lamarck, the mouth is semilunar, the pillar callous and compressed below. The *H. neritella*, (Lister, *Conch.* tab. 61. fig. 59), is the representative of the genus.

In the genus *MELANIA* of Lamarck, the shells are turreted, longer than broad, effuse at the base, with a twisted solid pillar. The *H. amarula* is the type.

The genus *MELANOPSIS* was instituted by Daubebard to include the shells termed *melaniæ* by Olivier in his voyage to the Levant. The mouth is lanceolate, the pillar truncated and emarginated above with a callosity at the base.

29. *NERITA*.—This genus has been subdivided by Adanson and Bruguière into *NERITA* and *NATICA*. In the former there is no umbilicus as in the *N. exuvia*, and, in the latter, there is an umbilicus, as in the *N. canrena*. Of the restricted genus *nerita*, we possess two species; the *littoralis*, common on our shores, and *N. virginea*. There are several species of *natica* of British growth, the largest of which is the *glaucina*. The fresh water species have been formed by Lamarck, with great propriety, into a distinct genus, under the title *Neritina*. The *N. fluviatilis* occurs in the English rivers.

30. *HALYOTIS*.—This genus has been dismembered of those species which are destitute of the perforations on the disc. These have been formed into a new genus termed *STOMATIA*.

31. *PATELLA*.—This genus, which at first sight appears so very natural, contains shells which exhibit considerable differences, both in form and structure, when narrowly examined. Geoffroy, with great propriety, separated the fluviatile species under the generic title *ANCYLUS*, a genus afterwards employed by Muller. The animal is essentially distinct from the marine *patellæ*. There are two species of this genus, the *lacustris* and *fluviatilis*, natives of Britain.

The genus *PATELLA*, as circumscribed by Lamarck, has been already sufficiently noticed. The common limpet may serve as the type of this genus.

In the genus *FISSURELLA*, established by Bruguière,

Mollusca. there is always an opening like a key-hole, near the summit of the shell. The *P. græca* and *apertura* are found on our coasts.

The genus *EMARGINULA* is readily distinguished by the slit or indentation which occurs on the posterior margin of the shell.

In the genus *CAPULUS* of Montfort, the shell is conical, with the summit produced into a beak, more or less recurved, and twisted. The *P. hungarica* of Lister is the type.

The genus *CONCHOLEPAS* is furnished with an operculum, and in form and habits approaches the buccinum. It is represented by the *P. integra* of Da Costa's *El. tab. 2. fig. 7.*

In the genus *CREPIDULA*, the cavity of the shell is partially interrupted by a simple diaphragm. The *P. porcellana* is the representative of this genus. The *C. chinensis* inhabits the British seas.

In the preceding genus, the first approach to the turbinated shell makes its appearance, which becomes more obvious in the genus *CALYPTRÆA*, in which the cavity is furnished with a spiral diaphragm. The *C. equestris* is the type of the genus, which is related in part to the trochi. From this genus of Lamarck, Montfort has separated the *INFUNDIBULUM*, as possessing a central spiral pillar. Sowerby has figured several species of this last genus in his *Mineral Conchology* as occurring in a fossil state in Britain.

The patella unguis now ranks as a bivalve, and constitutes the genus *LINGULA* in the acephalous family brachiopoda of Lamarck. Linnæus, who never saw more than one valve, placed it among the patellæ. Chemnitz, who examined both valves, considered it as a pinna. These writers had overlooked the figure of the perfect shell, with its tube or stalk, as given by Seba, vol. iii. fig. 16. No. 4. This specimen, which belonged to Seba, passed into the museum of the Stadtholder, and afterwards reached, in company with the spoils of the other Continental collections, the museum of Paris. Here Lamarck examined it, and formed his new genus. And the same specimen enabled Cuvier to investigate its anatomical structure, which he has explained in detail in the first volume of the *Annales de Museum*. Science, in this instance, as well as several others, profited by the successes of the late emperor of the French. This genus is destitute of a hinge. The valves are supported on a peduncle, and the shell is opened partly by the relaxation of the adductor muscle of the animal (and not by the external membrane, as stated by Mr. Sowerby), and partly by the issuing forth of its spiral arms, which push asunder the valves like a wedge.

Another genus was constituted and termed *ORBICULA*, from the *Patella anomala* of Müller, *Zool. Dan. vol. i. p. 14. t. 5.* The under valve is very thin, and fixed; the upper is orbicular, and depressed. It is a member of the same family as the preceding in the system of Lamarck.

32. *DENTALIUM*.—This very natural genus of Linnæus has undergone no alterations, nor has our knowledge of the inhabitant been satisfactorily enlarged. The *Dentalium imperforatum*, *trachea*, and *glabrum* of Montagu's *Testacea Britannica*, do not accord with the essential character of the Linnæan genus in being "utraq̃ue extremitate pervia."

33. *SERPULA*.—This genus has undergone several changes in the hands of modern conchologists. The *S. seminulum* has been transferred to the genus *miliola*, and the *S. filigranum* to the *tubipora*. Besides these trivial alterations, the character has been greatly circumscribed, so as only to include shells which adhere to other bodies, and are tubular, entire and flexuous, with a simple mouth, as represented by the *S. contortuplicata* of Linnæus. The species which are regularly spiral, discoid, and fixed, as the *S. spirorbis*, now constitute the genus *SPIRORBIS*. But as there are both dextral and sinistral shells with this character,

the dextral species may form the genus *Spirorbis*, while the *HETERODISCA* may receive the reversed species.

The genus *VERMICULARIA* is formed from those species which, in appearance, resemble the spirorbis, but are not adherent, such as the *S. lumbricalis*. The shell at the mouth is, in general, somewhat produced. There are two or three minute British shells of this genus.

The genus *SILICULARIA*, represented by the *S. anguina*, is distinguished from the serpula by a longitudinal, lateral, subarticulated fissure, which extends the whole length of the shell.

The genus *PENICILLUS* is formed from that curious shell the *S. penis*, and well known by the name of the watering-pot. The disk is perforated by a number of small holes.

34. *TEREDO*.—From this genus, now considered as a bivalve (the tube being regarded as an accessory covering), the *FISTULANA*, of which *T. clava* of Gmelin is the representative, has been separated. The external tube in this genus is closed at the posterior extremity, while in *teredo* it is open. The *S. polythalamia* forms, according to Lamarck, the genus *SEPTARIA*, and the two genera *XYLOPHAGA* and *CLAVAGELLA* have more recently been instituted.

35. *SABELLA*. This last genus of the Linnæan vermes testacea has been degraded from its rank in conchology. The covering consists of agglutinated particles of sand and fragments of shells, and bears no resemblance to the testaceous coverings of the true mollusca. It is now placed in company with the terebella, and the three preceding Linnæan genera among the *ANNELIDES*.

In the preceding brief review of the Linnæan genera of shells, the reader will probably have been astonished at those changes which have taken place. In this country we are so much accustomed to the artificial method both in zoology and botany, that we often reject, without sufficient consideration, the improvements which the study of the natural method has suggested. In the time of Linnæus, perhaps, the genera of the shells, with a few exceptions, were sufficiently numerous and commodious to embrace all the known species; but since the science has been cultivated with more zeal, in consequence, we must say, of the introduction of the natural method, the number of species has increased tenfold. New genera and orders, and other conventional divisions, have been formed, suited to the state of improvement of the science. The merit of all these improvements did not originate with Bruguière or Lamarck, whose names we have so often had occasion to mention. Many of the modern genera may be traced to the systems which prevailed before the days of Linnæus; systems which the Swedish naturalist, in his desire to simplify, when simplicity was impracticable, too incautiously disregarded.

CHAP. III.—SYSTEMATICAL DISTRIBUTION OF THE MOLLUSCA.

THE successful methodical disposition of molluscous animals, could not have been accomplished previous to labours similar to those of Cuvier and Lamarck; or until the shell and the contained animal were studied as connected objects. When thus contemplated, molluscous animals admit of arrangement into two great classes, or divisions, which may be distinguished from each other by well-defined characters. In the one, the presence of a head may be recognised, together with eyes, and even ears in some of the groups. In the other, containing animals much less perfect in their organization, there is no head, neither vestige of eyes or ears in any of the species. The former have been termed *Mollusca Cephalata*, the latter *Mollusca Acephala*. This arrangement was first employed by Baron Cuvier, and afterwards by Lamarck and other modern systematical writers.

Mollusca. In the last work of the former naturalist, this method is departed from, and the six classes to which we have already referred, are constituted of equal rank, instead of being placed in subordination to the two primary divisions under which they can be suitably distributed.

DIVISION I.—MOLLUSCA CEPHALA.

Head distinct from the body, bearing the lips or jaws.

The head, or the anterior part of the body on which Zoologists have bestowed that denomination, possesses more or less freedom of motion, and, on the dorsal aspect, supports either tentacula or eyes, frequently both. The animals of this division exhibit so many modifications of form and structure, in all the series of organs, that the positive characters which they possess in common are few in number. They easily admit, therefore, of subdivision into inferior groups which exhibit well-marked characters of distinction. Two of these groups occupy a primary rank, and admit of the others being included under them as subordinate sections. In the first of these, the animals are all inhabitants of the water, and perform their progressive motion through that element by organs fitted for swimming. They are destitute of any ventral disc on which to crawl. In the second group, including animals which inhabit the land, as well as those which live in fresh water and in the sea, progressive motion is performed by means of crawling along the surface of objects, the body resting on a ventral disc termed a foot.

SECT. I.—NATANTIA.—*Organs of progressive motion fitted for swimming.*

The organs of motion are situate near the anterior extremity of the body, and consist either of flexible tentacula or membranaceous expansions. All the species reside in the sea. They are nearly of the same specific gravity with the surrounding fluid in which they float about, having their motions in a great measure regulated by its changes. It is, however, probable, that, by means of some contractile movements, they are capable of varying their density, and of rising or sinking in the water. They swim slowly, even with their utmost efforts. The animals of this section belong to the classes which Cuvier has termed *Cephalopoda* and *Pteropoda*.

CLASS I.—CEPHALOPODA.

Fins in the form of tentacula, surrounding the mouth.

The Cephalopoda, in reference to their external appearance, may be regarded as consisting of two parts; the tunic or sac, which contains the viscera, and the head, surrounded by the tentacula. The skin is usually mottled with minute coloured spots, the colour varying in intensity in different spots, and even in different parts of the same spots. These are confined to a thin layer on the outer surface of the true skin. In a living state these spots change their colour in rapid succession as if a coloured fluid was expelled from them or replaced in variable quantity. The sac is, in some species, in the form of a purse, destitute of any appendages, while in others, it exhibits fin-like expansions. It varies considerably in its consistence: in some, it is strengthened on the back internally, by corneous ribs or testaceous plates, and in others, it is protected externally by spiral shells. In some species, it is connected with the head by an intervening space, which may be regarded as a neck, but in others, the tunic and head are continuous behind. In all, it exhibits, after death, great changes of colour.

On the summit of the head there is a flattened disc, in the centre of which is seated the mouth. Round the mar-

gin of this oral disc, which is strengthened by a band of muscular fibres, are placed the *arms* or tentacula. Beyond this circle of arms, in some species, there are situated two organs, larger in their dimensions than the arms, which may be denominated *feet*. Both the arms and feet are covered on their central aspect with numerous suckers, by which they are enabled to attach themselves to different bodies, and to seize their prey; and in their axis, both a nerve and artery may be observed. These arms and feet are capable of being moved, at the will of the animal, in every direction, and are the organs by which progressive motion is performed. In the space between the head and tunic in front, there is an opening or *funnel* with a projecting aperture. This funnel opens into the cavity of the sac, and serves both to convey water to the gills, and to carry off the different excreted matters.

The brain in the Cephalopoda is contained in an irregular hollow ring, in the cartilaginous border of the oral disk. This cartilage is thickest on the dorsal aspect, and contains the parts which have been denominated *cerebrum* and *cerebellum*, the remaining part of the canal being occupied with the collar, which surrounds the esophagus. The nerves, which proceed directly from the brain to the parts which they are destined to influence, are few in number. From the cerebrum a few small nerves issue, which go to the mouth, and the base of the feet, while some proceed to form ganglia at the mouth, and others supply the feet. The cerebellum, besides furnishing the collar which encircles the gullet, contributes to the formation of the large ganglia which supply the arms, the optic and auditory nerves, those for the funnel, the tunic, and the viscera. From the size of the animals, the ganglia of the nerves are very distinctly displayed. The anastomosing branches of the nerves of the arms are likewise conspicuous. Each nerve, at the base of each arm, sends out two filaments, one to the nerve of the arm on each side. In this manner a chain of nerves is formed round the base of the arm, probably calculated to enable them to act more readily in concert. From the abundant distribution of nerves to the different parts, it appears probable that the sense of touch exists in a tolerably perfect manner. There is no proof of the development of organs for the display of the senses of smell and taste.

The Cephalopoda are furnished with two eyes, one on each side of the head. The external membrane on the inner side, which may be compared to the *sclerotica*, differs in many particulars from the covering of the same name in the eyes of the vertebral animals. While it surrounds the contents of the eye from the entrance of the optic nerve to the pupil, it is greatly separated from the choroides. Immediately within its cavity, there is a bag, with a peculiar membranaceous covering, which contains numerous glandular bodies, similar to the milt of fishes, by which the eye is supported, and which probably act as secreting organs (although M. Cuvier could not detect any excretory canals), and likewise an expansion or ganglion of the optic nerve. The concave or anterior surface embraces the *choroides*. This membrane, after enclosing the vitreous humour, forms a zone or diaphragm, which may be compared to the ciliary processes, with an aperture in the centre for the reception of the crystalline lens. The circular margin of this aperture is lodged in a circular groove of the lens, and intimately united with it, so that the lens is divided into two unequal hemispheres. Its central surface is coated, as in the higher classes of animals, with the coloured mucous pigment which has been denominated *pigmentum nigrum*. In the cephalopoda, however, it is of a purplish-red colour.

The optic nerve, after entering the *sclerotica*, expands into a large ganglion, from the peripheral surface of which, issue numerous nervous filaments. These pierce the choroides by as many holes, and go to form, by their reunion, the retina. This important membrane extends to the cili-

Mollusca. ary zone, and, like it, appears to unite itself with the groove of the lens.

The vitreous humour is contained in a peculiar vesicle, having the lens seated in a concavity on its external surface. The lens divides easily into two parts, the line of separation being the groove which receives the ciliary ligament. The separated surfaces are flat, and the outer portion is in the form of a planoconvex lens. Each portion consists of a number of concentric layers of variable thickness, composed of radiated fibres, becoming less and less distinct towards the centre, near which the laminated and radiated appearances cease to be perceptible. An imperfect representation of this structure is given by Sir E. Home, probably from preparations by Mr. John Hunter, in the *Phil. Trans.* vol. lxxxiv. tab. 5. p. 26.

The conjunctiva supplies the place of a cornea, and covers directly the crystalline lens, as there is no aqueous humour. This membrane, in some, is continuous with the skin, but in others, there are imperfect eye-lids formed by its duplication, previous to passing over the lens. The skin, at the opening of the pupil, formed by the sclerotica, in the absence of an *uvea* and *iris*, is strengthened by a membrane which appears to be muscular, and probably assists in the contraction or enlargement of the aperture.

The animals of the cephalopodous class, besides containing complicated eyes, are likewise furnished with ears. These are situate in the annular cartilage which supports the arms. In this cartilage, there are two cavities, in each of which there is a bag filled with a gelatinous, transparent fluid, and containing a calcareous substance, differing in its consistence according to the species, from the brittleness of starch to the hardness of bone. The auditory nerve penetrates the walls of this labyrinth, and ramifies on the membranous bag which it contains. There is no external opening, nor any apparent alteration in the thickness of the investing integuments.

The digestive system of the Cephalopoda exhibits several appearances by which it may be distinguished. The arms which surround the mouth, seize the animals which are to serve as food, and bring them to the mouth. The mouth is situated in the centre of the disc, round which the tentacula are arranged. It is surrounded with a slight fold of the skin, which may be compared to lips, and which is rough on the central aspect. Within the lips are the two mandibles, of a deep brown colour, hard, horny consistence, and in form resembling the beak of a parrot. Where free, they are conico-tubular, but where covered, they are open at the central side. The under beak, unlike the same organ in birds, is the largest, the most crooked, and embraces the upper, or the one on the dorsal margin of the mouth. These jaws are merely able to open and shut, as they possess no lateral motion. They are supported by the muscular bed of the mouth, which serves as a mould to fill the cavity towards the point. The tongue is situate between the beaks, and is armed with reflected teeth. These teeth, in consequence of the undulatory motion of the substance of the tongue, expedite the progress of the food into the gullet.

The salivary glands are four in number, and are placed in pairs. The glands of the first pair, seated on each side of the muscular bed of the mouth, are divided into numerous lobes, the excretory ducts of which pour their fluid into the beginning of the gullet. The second pair, seated lower down and below the eyes, are not so much divided, and send out separate canals, which unite and pour their contents into the mouth.

The gullet is furnished with a lateral expansion, not unlike the crop of gallinaceous birds. The stomach is muscular, like the gizzard of fowls, and the cuticle is thick, and separates easily from the other membranes. At the pyloric opening of the stomach, there is another aperture equally

large, which leads into the *spiral stomach*, or *cæcum*, as it has been improperly termed by some anatomists. It may with greater propriety be denominated the duodenum, as it performs some of the offices of that part of the gut in the higher orders of animals. This stomach is conical, closed at the distal extremity, and performs about a turn and a half, like a spiral shell. Its inner surface is covered with a ridge, which traverses it in a closely spiral direction. The bile flows into it near the apex, and towards its base glandular orifices, pouring out a thick, yellow fluid, may be observed. The intestine, after leaving the pylorus, in some species, makes one or two turns, in others, it proceeds directly to the anus. This opening is seated at the base of the funnel, on its posterior or dorsal side.

The *liver* is of considerable size, of an orange-yellow colour, and of a soft and spongy texture. It gives rise to two hepatic ducts, which proceed to the extremity of the spiral stomach, where, by a common orifice, they empty the orange-coloured bile which they contain.

The organs of circulation consist merely of veins and arteries. The veins which have their origin in the feet, mouth, and annular cartilage, coalesce, and form two branches, which afterwards unite into a common trunk. This vessel, after descending through part of the viscera into the abdomen, divides into two branches, each of which may be considered as a *vena cava*, conveying the blood to the lateral hearts. Each *vena cava*, at its origin, is joined by an equally large vessel, which empties its contents in a direction nearly at right angles with the former. These veins arise in the stomach, intestines, liver, and organs of generation. The *vena cava* receives a second large vessel, nearly in the same direction as the first, which has its origin in the tunic and the supports of the branchiæ. From the size of the *vena cava*, in consequence of the union of these two branches, and the appearance of muscular ridges on its inner surface, it has been compared by some to an auricle.

On each side, in the common cavity of the tunic, and near the gills, an aperture may be observed, the entrance to a bag or cavity. Each cavity is traversed by the *vena cava* of that side, and in its passage exhibits a curious conformation. The surface of the vein is covered with spongy, glandular bodies of different shapes. These, upon being pressed, pour out an opaque, yellow, mucous fluid. Within, these glands communicate by very wide ducts with the cavity of the vein. Indeed, when air is blown into the vein, it readily passes through the glands into the bag, and thence into the cavity of the tunic; and when air is blown into the bag, it likewise penetrates the gland, and passes into the veins. The arteries with which these glands are furnished are comparatively minute.

It appears probable that these glands separate some principle from the blood, and that this is conveyed away by the ejection of the water from these venous bags into the common cavity. Were it practicable to analyse the yellow mucus which these glands contain, some light might be thrown on the subject. Indeed, it appears not improbable, that this arrangement is analogous in its functions to the urinary system in the most perfect classes.

Each *vena cava* enters its corresponding lateral heart or ventricle, through an intervening valve. Each lateral heart is situate at the base of each gill, is pear-shaped, black, and moderately thick, with numerous pits on its inner surface. Its narrow end terminates without any valvular structure in the pulmonary artery. In the genus *octopus*, the lateral hearts are naked; but in the genera *Loligo* and *Sepia*, there is suspended from each, by a slender footstalk, a spongy round body, which is concave beneath. The footstalk consists of fibres, which are attached to the surface of the heart, but there is no communication by ducts or vessels. The use of this organ is unknown.

The animals of this class continually reside in the water,

Mollusca. and respire by means of gills or branchiæ. These are double, one on each side, corresponding with the lateral pulmonic ventricles. Each gill is connected at its opposite sides to the tunic, by means of fleshy ligamentous bands. Between these, the double leaves of the gills are arranged in an alternate series. Each leaf is supported by a footstalk from the band, and is subdivided into smaller leaves, to expose a greater surface to the water.

The pulmonary artery passes along this band, sends a branch into each footstalk, which, penetrating the substance of the gills, conveys the blood to its different divisions.

The systemic veins depart from the gills at the opposite extremity. These unite at the inferior band, and from each gill a vessel proceeds to the single central or systemic heart or ventricle. In some of the animals of this class the systemic veins are somewhat enlarged, and assume the appearance of auricles. The two pulmonary, or rather the systemic veins, enter the heart at the opposite side, each at the termination being furnished with a valvular organization.

The systemic heart is white and fleshy, and differs according to the genera, in its form, being in the *Octopus* semicircular, but in the *Loligo* and *Sepia* lobed. Besides giving rise to a large aorta, or principal artery, two smaller ones likewise proceed from its cavity. These arteries are furnished at their entrance with valves.

The sexes in the Cephalopoda are distinct, the male and female organs being found on different individuals. There is not, however, any external mark by which they may be distinguished. M. Cuvier found that the males of the *Octopus* were scarcely a fifth part so numerous as the females.

The male organs of generation consist of the following parts: The *testicle* is a large white glandular purse, containing numerous fringed filaments, from which the seminal fluid is secreted. This fluid passes out of the testicle by a valvular opening, into the *vas deferens*. This canal is slender, and greatly twisted in its course, and opens into a cavity which has been compared to the *seminal vesicle*. The walls of this last cavity are strong and muscular, and disposed in ridges. Near the opening at the distal extremity of this sac is an aperture leading into an oblong glandular body, regarded as exercising the functions of a *prostate gland*. Beyond this lies a muscular sac, divided at the top, where it opens by two ducts, but connected at the base. In this sac are numerous white thread-like bodies, terminated by a filament, but unconnected with the sac. In the interior they consist of a spiral body, connected at each extremity with a glandular substance. When these bodies are put into water, they twist themselves in various directions, and throw out at one of their extremities an opaque fluid. These motions are not excited by placing them in oil or spirit of wine, but they may be exhibited by immersing in water those which have been kept for years in spirits.

These bodies, first observed by Swammerdam, and afterwards by Needham, have been regarded by some as demonstrating the truth of the vermicular theory of generation; by others, they have been considered as analogous to the pollen of plants, their tunic is in part soluble in water, and when they are thrown into that fluid, they speedily burst, and spread their impregnating contents over the eggs of the female. Although this last conjecture is plausible, and countenanced by the circumstance that these vermicular bodies are only found at the season of reproduction, the subject is still involved in obscurity. Are these bodies produced in the testicle, and only brought to this bag when nearly ready for exclusion; or, if the product of the bag itself, by what means are they nourished?

The male organs terminate in a cylindrical fleshy body termed the Penis. This is hollow within, and ribbed with muscular bands. Near its base it receives one of the ducts of the vermicular sac, continuous with the one from the prostate gland, forming its canal, and toward the apex the other

Mollusca. duct. It projects but a short way into the cavity of the great bag, into which it empties its contents. These pass out of the body at the funnel-form opening in the throat.

The female organs of generation consist of an ovarium and oviduct. The ovarium is a glandular sac, to which the ova are attached by footstalks. The opening by which they issue from the ovarium is wide, and the oviduct (in the *Octopus vulgaris* and *Loligo sagittata*.) after continuing a short way simple, divides into two branches, each having its external aperture near the anus. The oviducts are furnished within with muscular bands and a mucous lining, and encircled with a large glandular zone, destined, probably, to secrete the integuments of the eggs. In the *Loligo vulgaris*, and the *Sepia*, the oviduct continues single. Besides these organs, the *Loligo vulgaris* and *sagittata*, and the *Sepia*, have two large oval glandular bodies, divided by transverse partitions, with their excretory ducts terminating at the anus, the use of which is unknown. The eggs, of the peculiar form already noticed, pass out of the funnel, after which they are supposed to be impregnated by the male, according to the manner of fishes.

The *inky fluid* now remains to be considered, as the most remarkable of the productions of this tribe of animals. The organ in which this fluid is secreted is spongy and glandular. In some species it is contained in a recess of the liver, which has given rise to the opinion, that the coloured fluid which it secreted was bile. In other species, however, this gland is detached from the liver, and either situate in front or beneath that organ. The excretory canal of this gland opens in the rectum, so that the fluid escapes through the funnel. It mixes readily with water, and imparts to it its own peculiar colour. When dried, it is used as a pigment, and is considered as the basis of China ink. It is regarded by Signior Bezio as a peculiar substance which he has denominated *Melaina*. It is obtained by digesting the ink with very dilute nitric acid, until it become yellowish, washing it well, and separating it by the filter; it is then to be frequently boiled in water, one of the washings to be a little alkalinized; and, finally, with distilled water. The *melaina* is a tasteless, black powder, insoluble in alcohol, ether, and water, whilst cold, but soluble in hot water; the solution is black. Caustic alkalis form with it a solution even in the cold, from which the mineral acids precipitate it unchanged. It contains much azote. It dissolves and decomposes sulphuric acid. It easily kindles in the flame of a candle. It has been found to succeed as a pigment in some respects, better than China ink. (*Dub. Phil. Trans.* Nov. 1825.)

The Cephalopoda are all inhabitants of the sea. They are widely distributed, occurring in the arctic as well as the equatorial seas. In the latter, however, they grow to the largest size. It is reported, that in the Indian seas, boats have been sunk by these animals affixing to them their long arms, and that they are dreaded by divers.

The two Linnæan genera, *Nautilus* and *Sepia*, comprehend all the animals which are at present considered as belonging to this class.

ORDER I.—NAUTILACEA.

Furnished with a multilocular shell.

This order is involved in the greatest obscurity. None of the recent species have been subjected to an accurate examination, so that their connection with the order Sepiacea may still be considered doubtful. Enough is known of the animals of two of the genera, to furnish some hints for those who are fond of classifying animals from their analogies. These genera are *SPIRULA* and *NAUTILUS*.

In the *Spirula*, the shell, which is concealed under the skin of the back, is spiral, with the whorls separate, the mouth orbicular, the chambers perforated by a pipe, and

Mollusca. the last cell produced into a tube. The position and use of this terminal tube are unknown. The *S. vulgaris* is the most common species, and inhabits the seas in the West Indies. In the restricted genus *Nautilus*, the shell is supposed to be external, and the body of the animal to be lodged in the last chamber, and to be fixed by a ligament which descends into the central pipe. In the shell itself, the turns of the spire are contiguous, and the last whorl embraces the others on the sides. The *N. Pompilius* of RUMPHIUS is the only species in which the animal has been detected.

The other genera which have been formed in this order depend exclusively on the characters furnished by the shells; and the resemblance which these bear to the preceding genera, constitutes all their claim to be included in the present order.

ORDER II.—SEPIACEA.

Destitute of a multilocular shell.

The sac is strengthened by horny or testaceous plates, unless where the habits of the animal render such support unnecessary.

1. Head surrounded with eight arms and two feet.

The two feet are nearly similar in their structure to the arms, or tentacula, but considerably larger in their dimensions. They have their origin on the ventral side of the mouth, between that organ and the funnel. The suckers are pedunculated, with their margin strengthened by a corneous ring, furnished with teeth. The sac is furnished with fin-like expansions, and strengthened internally by corneous or testaceous ribs or plates. The head is divided from the sac on all sides by a neck. The margin of the anus is surrounded with tentacula.

GENUS SEPIA. The sac is furnished on each side throughout its whole length with a narrow fin.

The suckers are irregularly scattered on the arms and feet. The back is strengthened by a complicated calcareous plate, lodged in a peculiar cavity. This plate has been long known in the shop of the apothecary under the name *Cuttle-fish bone*, which was formerly much prized in medicine as an absorbent, but is now chiefly sought after for the purpose of polishing the softer metals. It is somewhat ovate, flatly convex on both sides, and thickest where broadest. The superior half, or the one next the head, is the longest, rounded at the extremity, and thin. The inferior portion becomes suddenly narrow, and ends in a point. It may be considered as consisting of a dermal plate, concave on the central aspect, having its concavity filled up with layers which are convex on their central aspect.

According to our observations, the dermal plate appears to consist of three different laminae, arranged parallel to one another. The external or dorsal layer is rough on the surface, and marked by obscure, concentric arches towards the summit, formed by minute knobs, which become larger towards the base, where they appear in the form of interrupted transverse ridges. It is uniform in its structure, and the tubercles possess a polish and hardness equal to porcelainous shells, although they blacken speedily when put in the fire, and contain a good deal of animal matter. On the central side of this layer there is one flexible and transparent, similar to horn, and smooth on the surface. The third layer is destitute of lustre; and, in hardness and structure, resembles mother-of-pearl shells.

The layers which fill the concavity of this dermal plate are slightly convex on the central aspect, and are in part imbricated. Each layer is attached to the concave surface of the dermal plate, by the upper extremity and the two sides, while the inferior or caudal extremity is free. The inferior and first formed layers are short, occupy the base and middle, and rise from the plate under a more obtuse

angle than the new formed layers, which are both the longest and the broadest.

Each layer, which is about one-fiftieth of an inch in diameter consists of a very thin plate, the dermal surface of which, when viewed with a magnifier, exhibits numerous brain-like gyrations. From the ventral surface of this plate arise numerous perpendicular laminae, which, when viewed laterally, appear like fine parallel threads, but when examined vertically, are found to be waved, and fold upon themselves. Next the plate they are thin, and not much folded; but towards their other extremity they become thicker, striated across, and more folded, with irregular margins. On the thick, tortuous even ends of these laminae, the succeeding plate rests, and derives from them the peculiar markings of its surface. These laminae are closely set, irregularly interrupted, and occasionally anastomose. M. Cuvier states, erroneously, (*Mém. sur la Seiche*, p. 47.) that these laminae are hollow pillars disposed in a quincunx order.

The term *bone* has been improperly applied to this complicated plate; "for," according to Mr. Hatchett, (*Phil. Trans.* vol. lxxxix. p. 321.) "this substance, in composition, is exactly similar to shell, and consists of various membranes, hardened by carbonate of lime, without the smallest mixture of phosphate."

The most remarkable species of this genus is the *Sepia officinalis*, which is distinguished from the others by its smooth skin. It inhabits the British seas, and although seldom taken, its bone is cast ashore on different parts of the coast, from the south of England to the Zetland isles.

GENUS LOLIGO. Calamary. Sides of the sac only furnished partially with fins.

The suckers are disposed on the arms and feet in a double row. The dorsal plate is flexible and corneous, imbedded in the substance of the sac, and is multiplied with years. Dr. Leach has described three new species of the genus *Loligo*, which were collected by Mr. Cranch during the voyage to the Congo, in that unfortunate expedition under the direction of Captain Tuckey. These species belong to a group which have the suckers produced into hooked processes. In two of these species, *L. leptura* and *Smithii*, the suckers on the arms, as well as the feet, are produced into hooks, while, in one species, *L. Banksii*, the feet only are armed with hooks.

The same distinguished naturalist has instituted a new genus nearly allied to *Loligo*, from two species collected during the same voyage. The following characters are assigned to it.

"GENUS CRANCHIA.—Body oval, sac-shaped; fins approximating, their extremities free; neck with a frenum behind, connecting it with the sac, and with two other frena, connecting it with the sac before.

"Sp. 1. *Cranchia scabra*.—Sac rough, with hard, rough tubercles.

"Sp. 2. *Cranchia maculata*.—Sac smooth, beautifully mottled with distant ovate spots." (*Narrative of an Expedition to explore the river Zaire, usually called the Congo in South Africa, in 1816, under the direction of Captain J. K. Tuckey, R. N. London, 1818, p. 410.*)

Head surrounded with Eight Arms without Feet.

The suckers have soft margins. The sac is destitute of fin-like expansions, and is either simple or strengthened in the interior by two short corneous processes. The head is united with the sac behind, without the intervention of a neck.

a. Arms all equal in Size.

GENUS OCTOPUS.—Suckers arranged in a double row.

The suckers are sessile. The oviduct is double. The margin of the anus is simple. The *Sepia octopodia* of Lin. is the type of the genus.

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GENUS ELEDONA.—Suckers on the arms disposed in a single row.

M. Lamarck has figured and described two species of this genus, in the *Mém. de la Soc. d'Hist. Nat.* One of these is a native of the Mediterranean, and is remarkable for giving out an odour like musk.

b. Arms unequal.

GENUS OCYTHOE.—Two of the arms at their inner extremities furnished with membranaceous expansions.

In this genus, which was instituted by M. Rafinesque, the suckers are in a double row, and supported on footstalks. In the specimens of the *Ocythoe Cranchii*, procured during the expedition to the Congo, Dr. Leach observed "four oblong spots on the inside of the tube, resembling the surfaces for the secretion of mucus, two inferior and lateral, and two superior, larger, and meeting anteriorly. On the rim of the sac, immediately above the branchiæ, on each side, is a small, short, fleshy tubercle, which fits into an excavation on the opposite side of the sac." (*Phil. Trans.* 1817.)

This animal was long considered as the fabricator of the shell termed Argonauta or Paper Nautilus. The observations of Mr. Cranch, the zoologist to the Congo expedition, were supposed to have demonstrated that the shell is merely the temporary residence of this animal, which it quits at pleasure. The body of the animal does not conform in shape to the cavity of the shell, nor to all its irregularities of surface; neither is there any muscular attachment between them. "On the thirteenth of June," (says Dr. Leach, when publishing the notes of Mr. Cranch,) "he placed two living specimens in a vessel of sea-water; the animals very soon protruded their arms, and swam on and below the surface, having all the actions of the common *Polypus* (octopus) of our seas; by means of their suckers, they adhered firmly to any substance with which they came in contact, and when sticking to the sides of the basin, the shell might easily be withdrawn from the animal. They had the power of completely withdrawing within the shell, and of leaving it entirely. One individual quitted its shell and lived several hours swimming about, and showed no inclination to return into it; and others left the shells as he was taking them up in the net. They changed colour, like other animals of the class Cephalopoda; when at rest, the colour was pale flesh-coloured, more or less speckled with purplish; the under parts of the arms were bluish-grey; the suckers whitish." The specimens which furnished an opportunity for making the preceding observations, were met with in the Gulph of Guinea, and afterwards on the voyage, swimming in a small argonauta, on the surface of the sea. The reader, who is desirous of farther information on this subject, may consult Dr. Leach's *Observations on the Genus Ocythoe of Rafinesque*, Sir E. Home on the *Distinguishing Characters between the Ova of the Sepia, and those of the Vermes Testacea that live in water*, in the *Philosophical Transactions* for 1817, art. xxii. and xxiii., (both of which are added to the appendix of Captain Tuckey's *Narrative*.) and a paper by Mr. Say, on the genus *Ocythoe*, in the *Phil. Trans.* 1819, art. vii. More recently, however, naturalists seem disposed to reunite the *Ocythoe* with the *Argonauta*, though the question cannot be considered as determined.

CLASS II.—PTEROPODA.

Fins formed of membranaceous expansions.

This class was instituted by Cuvier, for the reception of a few genera, the peculiar characters of which indicated the impropriety of suffering them to remain in any of those categories which had been previously established. All the species are small in size; and the attempts hitherto made to investigate their internal structure, have, in a great

measure, failed in explaining the functions of the organs which are exhibited. The valuable papers of Cuvier, on the *Clio*, *Pneumodermon* and *Hyalea*, include nearly all the accurate information on the subject, of which naturalists are in possession.

The general form of these animals is somewhat ovate. The tunic appears in some genera, as the *Clio* and *Pneumodermon*, to be double, the external one soft and thin, the internal exhibiting a fibrous structure, corresponding to the muscular web of the skin of the higher classes. In these animals, however, the two layers are unconnected throughout the greater part of their expansion. In some, as the *Cymbullia*, the tunic is cartilaginous, while in others it is strengthened by a shell. In these last, the shell in the *Limacina* is a spiral univalve, covering the abdominal viscera, and in the *Hyalea*, where it serves the same purpose, it approaches in character a bivalve shell. It is, however, destitute of a hinge, the two valves being united together at their caudal margins, and there is no appearance of a transverse adductor muscle.

The organs of motion in all the genera consist of two fins, or membranaceous expansions, one being seated on each side of the head. They have no foot wherewith to crawl, nor any suckers by which they can adhere to objects. They are, therefore, free animals moving about in the water by means of their fins, and probably possessing, at the same time, a power of varying their specific gravity, as they are capable of varying, to a certain extent, the form of their bodies, and of enlarging or reducing their dimensions. There is nothing peculiar in their nervous system.

The organs of digestion differ greatly from those of the Cephalopoda, which we have already considered. They are generally regarded as destitute of eyes and ears. Their tentacula are either seated on the head, forming two complicated branches of filaments, or spread along the margin of the tunic. There are no arms for seizing the food. The mouth, however, is furnished with lips; and in some there is an appearance of a tongue at the entrance of the gullet. The salivary glands are two in number, lengthened, descending a considerable way into the abdomen, and pouring their contents, by means of their excretory canals, into the cavity of the mouth. The gullet, after being encircled by the nervous collar, suffers an enlargement, which has been termed a crop, contiguous to which is the stomach. Both these cavities exhibit muscular ridges on the inner surface. The liver surrounds the stomach, is intimately united with its contents, and pours in its bile by numerous pores. The intestine is short, and, after making one or two turns, ascends and terminates in the neck near the mouth.

The circulating system in this class has been but very imperfectly investigated. The pulmonic vessels are unknown, but systemic veins, a single auricle, ventricle, and aorta, have been detected. The heart, in some, is situated on the left, in others, on the right, side of the body.

The aërating organs exhibit very remarkable differences. In the *Clio* they are in the form of a fine net-work on the surface of the fins; in the *Pneumodermon* they are conjectured to form leaf-like ridges on the caudal extremity of the body; or if these ridges are to be considered as particular kinds of fins, the gills may be sought for on the membranaceous expansions of the neck. In the *Hyalea* the branchiæ form a complex band on each side of the body, at the lateral opening of the shell.

The animals of this class are all hermaphrodites. There is a common cavity, a vesicle, penis, vas deferens, and testicle, together with an oviduct and ovarium. These open near the mouth on its ventral margin. There is nothing known with respect to the appearance of the eggs, the period of propagating, or the form of their young.

All the animals of this class inhabit the sea. Some, as the

Mollusca. Clio and Limacina, frequent the arctic regions, and afford the whale a great part of its sustenance. None of the species have hitherto been detected in the British seas.

M. Cuvier divides the animals of this class into cephalous and acephalous. In the latter division he places the genus *hyalea*. The head of the animal of this genus, with its inferior neck, may, however, be sufficiently recognised to remove all doubt of its existence.

The characters which may be employed in the classification of this group are numerous; but the influence which their different forms exercise on the habits of the species is still unknown. The following disposition of the genera, though it has no claims to a natural division, may be useful to the student in his investigations.

(1.) *Tunic Strengthened by a Shell.*

GENUS LIMACINA.—Posterior extremity of the body covered by a spiral shell.

The shell, which is very tender, makes one turn and a half, is flat on one side, with a large pillar cavity on the other. The fins are two in number, one on each side of the neck. When the animal swims, the head with the fins are protruded.

This genus was instituted by Cuvier, for the reception of the *Clio helicina* of Captain Phipps, or *Argonauta arctica* of Fabricius. According to Mr. Scoresby, it is found in great quantities near the coast of Spitzbergen.

GENUS HYALEA.—Posterior extremity of the body protected by two connected shelly valves.

In the animals of this genus, the body is lodged between two plates or valves, united at the base, where they inclose the caudal extremity. The ventral valve is nearly flat, with an uneven margin, narrow anteriorly, but expanding behind, and terminating in three projecting points. From the middle point four ribs diverge forward, and a muscle arises, which, fixed in the superior viscera, enables the animal to withdraw into the shell. The dorsal valve is shorter than the preceding, the margin flat and circular, and the middle convex outwardly. The branchiæ are situate in the space between the lateral margin of the two valves, on each side, in a duplicature of the tunic, the sides of which are furnished with filaments. The fleshy neck supports the two membranaceous expansions; between which and the base the mouth is situate, surrounded by two lips, and strengthened within by two fleshy cheeks. The opening of the anus and oviduct are at the base of the right fin.

The *Hyalea tridentata*, the best known species of the genus, was first noticed by Forskal, in his *Descriptiones Animalium*, p. 124, as an Anomia, and inhabiting the Mediterranean. The same species was likewise taken in abundance in the Gulf of Guinea, by the expedition under Captain Tuckey.

(2.) *Tunic destitute of a Shell.*

A. Fins double.

Posterior extremity with leaf-like ridges.

GENUS PNEUMODERMON.—Head with two bundles of tentacula.

The body is oval, with a narrow neck, and a fin on each side. The mouth is nearly terminal, furnished on each side with a fleshy lip, and beneath, with a fleshy chin. Each tentaculum consists of a filament, with a tubercle at the end, pierced by a small hole, and considered as exercising the office of a sucker. Cuvier, in his *Mémoire sur l'Hyale et le Pneumoderme*, considered the leaf-like ridges which occur on the caudal extremity of the body, as the branchiæ, and even describes the pulmonary vein which conveys the blood from these to the heart. But, in his *Règne Animal*, he states it as the opinion of M. Blainville, that the fin-like expansions of the neck contain the branchiæ on their surface, as in the case of *Clio*. The rectum and oviduct terminate under the right wing. Cuvier has figured and described the only known species, which he terms *Pneumo-*

dermon Peronii, the trivial name being in honour of the discoverer, M. Peron.

Posterior extremity simple.

GENUS CLIO.—Body ovate, with the tunic elongated and membranaceous.

The head is divided into two lobes, the summits of which are furnished with tentacula. The existence of eyes has not been ascertained. The mouth is transverse, with two lateral longitudinal lips. On each side of the neck arise two blunt, conical, fin-like expansions, with a fine reticulated surface, considered as serving the double purpose of fins and branchiæ. The anus and orifice of generation terminate under the base of the right branchia. The viscera do not fill entirely the cavity of the inner bag. The gut makes only one fold.

The genus *Clio* was originally instituted by Brown in his *Natural History of Jamaica*. It was afterwards embraced and modified by Linnæus and Pallas, in such a manner as ultimately to exclude the species for the reception of which Brown originally formed it. It contains two species, the most remarkable of which is the *Clio borealis*. Mr. Scoresby, in his valuable work on the Arctic Regions, states, (vol. i. p. 544), that it occurs in vast numbers in some situations near Spitzbergen, but is not found generally throughout the arctic seas. In swimming, it brings the tips of the fins almost into contact, first on one side and then on the other.

GENUS CLEODORA.—Body covered with a triangular pyramidal tunic.

The fins are membranaceous. The mouth is situate between these, and is furnished with a semicircular lip. This genus was instituted by Peron, for the reception of the *Clio* of Brown. The *C. pyramidata* is the best ascertained species. Brown's *Jamaica*, p. 386, tab. 43, f. 1. Two other species were taken by the Congo expedition, in S. lat. 2. 14., and E. long. 9. 55., and S. lat. 2. 41., E. long. 9. 16., "both having a spinous process on each side of their shell, near its opening. One species is beautifully sulcated transversely, and the other but slightly so."—*Tuckey's Narrative*, p. 412.

B. Fin single.

GENUS CYMBULIA.—Tunic cartilaginous and trough-shaped.

The fin is single, divided into three lobes, one of which is small, with two tubercles, and a minute fleshy beard. This genus was instituted by Peron, in *Annales du Museum*, t. xv. t. 3, f. 10, 11.

SECT. II.—GASTEROPODA.—*Organs of Progressive Motion fitted for Creeping.*

This is one of the most extensive groups of molluscos animals. The marks by which it is distinguished are well defined, and the external and internal characters of the species have been successfully illustrated.

The Gasteropoda may be considered as having the body protected dorsally by the cloak, and ventrally by the foot. The *cloak* is either *continuous*, and usually more or less arched, for the reception of the viscera underneath, or it is *interrupted* by a projecting bag, in which are contained the principal digestive and reproductive organs. This projecting bag is tapering and spiral, and always protected externally by a shell. When the cloak is continuous, the surface is variously marked, and frequently exhibits a particular portion more elevated than the rest, in some cases concealing a testaceous plate, which has been termed the *shield*.

The *foot* situate on the ventral aspect, and in opposition to the cloak, exhibits a flat, soft surface, consisting of interlaced muscular fibres. Its central surface serves as a support to the viscera, while externally it constitutes the organ of progressive motion. It is a *sucker* rather than a foot, and enables the animal to adhere to objects when at rest, and to crawl from one place to another by a succession of

Mollusca. adhesions, not unlike the leech. It is also used as a fin in swimming.

By the union of the cloak and foot laterally and posteriorly, a sac is formed, which is open in front for the protrusion of the neck and head. The line of junction between the cloak and foot is marked, in general, by peculiarities in the condition of the margins of both.

The *neck* is usually divided from the cloak by a *collar*, or thickened margin belonging to the cloak, or rather to the shield, while in other cases it is continuous. Underneath, the neck is frequently attached to the foot.

The *head* supports the tentacula and eyes, is free dorsally, but frequently intimately connected with the foot on its ventral side. The portion between the tentacula and the mouth is termed the *snout*, (*le muse* of the French, and its margin *le chaperon*). The mouth exhibits various modifications of fleshy lips and corneous jaws. The inside of the cheeks are covered in some species with reflected teeth, to aid deglutition. The *tongue* can scarcely be detected in some of the genera; while, in others, it is a simple tubercle, or a strap-shaped, spiral organ, armed with transverse rows of teeth. This spiral tongue, where it is fixed to the base of the mouth, is broadest, and there also the spinous processes are strongest. The spiral part is narrowest and softest, and folded up behind the pharynx. M. Cuvier conjectures, and apparently with plausibility, that the spiral portion comes forward into the mouth to act as a tongue, in proportion as the anterior part is worn by use and absorbed. (See his *Mémoire sur la Vivipare d'eau douce*, p. 12; and *Mém. sur la Patelle*, p. 17).

The organs of respiration exhibit the two modifications of lungs and gills, to enable us to divide the Gasteropoda into two classes, which we have termed Pulmonifera and Branchifera. M. Cuvier appears to have been in some measure aware of the importance of the distinction, when he instituted his order *Pulmonés*; but he afterwards suffered himself to be more influenced by the presence of an operculum, the shape of the aperture of the shell, and the supposed separation of the sexes, than by the characters of the respiratory organs.

Some shells are simply tubular or conical; but the greater part are variously convoluted, the volutions being termed *whorls* or *spires*. These whorls are in general visible and distinct, the boundary between each being termed the *line of separation*. The whorls in some species are simply placed in a lateral position, while in others the whorls are formed upon a *pillar*, or *columella*, which runs in the direction of the axis of the shell, the inferior whorl in this case embracing the superior one. The pillar is in some cases nearly solid, in other instances tubular, with its base either open or covered. When the base of the tube of the columella is uncovered, the opening is termed the *pillar cavity*, or *umbilicus*.

In general, when a spiral shell is placed upon its base or mouth, with the apex towards the observer, the mouth will be found situated on the right side, and the whorls will be observed revolving in a direction from right to left, or corresponding with the motion of the sun. These shells are termed *dextral*. A few species have this order reversed, as the observer will readily perceive. For upon placing the shell in the above-mentioned position, the mouth will be found situated on the left side, and the whorls will revolve from left to right. These shells are termed *sinistral*, *heterostrophe*, or *heteroclite*.

CLASS I.—PULMONIFERA.

The pulmonary cavity is single and lateral. Its orifice is capable of being closed at the will of the animal. The bloodvessels are spread, chiefly on the walls and roof, like delicate net-work. The opening of the cavity is usually on

the right side, with the anus behind it, and the sexual orifice is in the front near the head. In some of the genera, these openings are situated on the left side. The shells of the former are denominated *dextral*, of the latter *sinistral*. This change in the position of the external openings is accompanied by a corresponding alteration in the arrangement of the internal organs. The heart, for example, is always placed on the side opposite the pulmonary cavity. In the dextral shells, therefore, it is sinistral. In both kinds, however, all the organs preserve the same relation to the back and belly, the head and tail. It is impossible, therefore, to conceive a dextral animal changed into a sinistral, by any circumstance which could take place at the period of hatching, as M. Bosc was inclined to believe. This arrangement of the organs must have been not merely congenital, but coeval with the formation of the embryo. In some species all the individuals are sinistral, while in others the occurrence is rarely met with in a solitary example. The former are in their natural state, the latter ought to be regarded as monsters. Where the character is permanent, it should constitute a generical difference.

The reproductive system of the animals of this class exhibits the sexual organs, in general, united in the same individual. Mutual impregnation, however, is necessary. All the species are oviparous. The eggs are either naked, as in the terrestrial genera, or enveloped in a gelatinous mass, like the aquatic kinds. The embryo acquires nearly all its members while in the egg, and the shell is of a proportional size previous to hatching. Sir Everard Home, when treating of the distinguished characters between the ova of the sepia, and those of the vermes testacea that live in water, (*Phil. Trans.*, 1817, p. 297), and when referring to the ova of the vermes testacea, says, "If the shell were formed in the ovum, the process of aërating the blood must be very materially interfered with, for this reason, the covering or shell of the egg, first drops off, and the young is hatched before the shell of the animal is formed; this I have seen take place in the eggs of the garden snail, but in the testacea that live in water, the young requires some defence in the period between the egg being hatched and the young acquiring its shell, which is not necessary in those that live on land; for this purpose the ova are enclosed in chambers of a particular kind." The assertion here made, and founded on *a priori* considerations, that the shell is not formed until after the egg is hatched, is opposed by every observation which we have been able to make on the subject; and what is more surprising, it is at variance with his own observations on the garden snail, the very example produced in its confirmation. The eggs of a snail, laid on the 5th of August 1773, were hatched on the 20th of that month, and their condition at this time distinctly stated. "On the 20th," he says, "the young were hatched, and the shell completely formed." It is much more becoming in a philosopher to observe how nature operates, than to pronounce what she *must* do.

ORDER I.—TERRESTRIAL.

The animals of this order reside constantly on the land. When by accident they fall into the water, they appear to be incapable of using their foot as a sucker or as a fin, and die after a few writhings. The species in general prefer moist places, and are seldom very active in dry weather. After a shower they speedily leave their hiding places, and at this time they may be readily collected. The eggs are hatched on land.

1st Subdivision.

Cloak and foot parallel, and containing the viscera between them.

In this group are included those animals denominated slugs in this country. They possess four retractile tenta-

Mollusca. cula, of unequal length, though in some cases one pair is obsolete. The eyes are two in number, in the form of black points, seated at the tips of the posterior tentacula.

In some of the genera the cloak is furnished with a shield, which is, in general, strengthened internally by a deposition of earthy matter, in the form of grains, or a shelly plate.

The shield in several of the genera is placed anteriorly, or the shield is placed nearer the head than the tail. The group thus distinguished contains four genera, two of which have compound tails, or furnished with peculiar organs, while in the remaining genera the tails are simple. The mouth consists of lips, which are capable of small extension, and above, the entrance is armed with a concave corneous jaw, with a notch in the middle. The tongue is merely armed with soft transverse ridges, pointed before, and terminated by a short cartilaginous cone. There is a sensible dilatation of the gullet, which marks the place of the stomach, at the under extremity of which is the rudiment of a cœcum at the pyloric opening. The intestine makes several folds, chiefly on the liver, before it reaches the anus. The salivary glands reach to the extremity of the gullet. The liver is divided into five lobes, which give rise to two ducts that open into the pylorus.

The circulating system consists of two venæ cavæ, which give out numerous branches to the pulmonary cavity. The aerated blood is conveyed by several ducts to a simple membranaceous systemic auricle. Between the auricle and ventricle there are two valves. The ventricle is more muscular than the auricle. The arteries, which take their rise from a single aorta, are characterised by a peculiar opacity, and whiteness of colour, as if they were filled with milk.

The organ of viscosity nearly encircles the pericardium. It consists of regularly pectinated plates. Its excretory canal terminates at the pulmonary cavity.

The organs of generation consist, in the female parts, of an ovary, oviduct, and uterus; and in the male, of a testicle, vas deferens, and penis, together with the pedunculated vesicle; and, as common to both the sexual organs, there is a cavity opening externally, in which, by separate orifices, the uterus, penis, and vesicle, terminate.

As it would be impracticable to give, even in the most condensed form, the characters of the numerous genera which have been instituted, from our limited space, we shall rather call the attention of the reader to the structure of a few of the more remarkable genera.

GENUS ARION.—A mucous orifice at the termination of the cloak.

This genus was instituted by M. le Baron D'Audebard de Férussac, in his *Histoire Naturelle Générale et Particulière des Mollusques Terrestres et Fluviales*, folio, Paris, 1819, 3e. liv. p. 53. The species of which it consists were formerly confounded with those which now constitute the restricted genus *Limax*. It differs, however, in possessing the mucous pore, in the pulmonary orifice being near the anterior margin of the shield, with the sexual orifice underneath, and in the soft state of the calcareous matter, in the shield. The author now quoted, has described four species, and illustrated their characters by beautiful and expressive figures. The *Limax ater* (together with its variety *rufus*) of British writers may be regarded as the type of the genus. The genus *PLECTROPHORUS*, distinguished by a conical protuberant shell at the termination of the cloak, was likewise instituted by M. Férussac, and nearly resembles the preceding in form. Three species have been described and figured, which, however, differ remarkably from one another.

GENUS LIMAX.—Pulmonary orifice near the posterior margin of the shield. This genus, as now restricted by M. Férussac, differs from the *Arion* in the absence of the caudal mucous pore, the position of the pulmonary cavity, and by the orifice of the sexual organs being placed under

the superior right tentaculum. The calcareous matter of the shield is more solid, and appears as a shelly plate.

In the following genus the shield is placed nearer to the tail than in the preceding group, and is fortified internally with a subspirial plate.

GENUS PARMACELLA.—Posterior extremity of the shield containing the shell. The pulmonary cavity is placed underneath the shell of the shield. This arrangement occasions a corresponding posterior position to the heart. Along the back, from the shield to the head, are three grooves, the middle one of which is double. The shield itself adheres only at the posterior portion, the anterior part being free. The internal structure is similar to the slugs. The only marked difference, indeed, consists in two conical appendages of the sexual cavity, by which there is an approach to the species of *Helix*.

The *Parmacella Olivieri* is the best known species, and was first described, and its structure unfolded, by M. Cuvier. It was brought from Mesopotamia by M. Olivier.

In the two following genera the cloak is destitute of a shield, and the pulmonary cavity is situated near the tail.

GENUS TESTACELLA.—Tail covered with a single spiral shell, underneath which is the pulmonary cavity. The vent and pulmonary cavity are, from the position of the protecting shell, on which they are dependent, nearly terminal. The foot extends on each side beyond the body. From the manner in which the blood is aerated, the auricle and ventricle are placed longitudinally, the latter being anterior.

GENUS ONCHIDIUM.—Cloak tuberculated. Snout enlarged and emarginate. Tentacula two in number, with eyes at the tips. This genus was instituted by Dr. Buchanan, (now Hamilton), in *Lin. Trans.*, vol. v. p. 132, for the reception of a species which he found in Bengal, on the leaves of *Typha Elephantina*. It is not, according to this naturalist, "like many others of the worm kind, an hermaphrodite animal; for the male and female organs of generation are in distinct individuals. I have not yet perceived any mark to distinguish the sexes, while they are not in copulation; as, in both, the anus and sexual organs are placed in a perforation, (cloaca communis), in the under part of the tail, immediately behind the foot; but, during coition, the distinction of sexes is very evident, the penis protruding to a great length, considering the size of the animal."

2d Subdivision.

Cloak and foot not parallel; the viscera contained in a spiral, dorsal protuberance, protected by a shell.

This group includes the animals usually denominated **SNAILS**. They bear a very close resemblance to the slugs. The shield, however, has a thickened margin in front, destined to secrete the matter of the shell. In the part corresponding with the centre of the shield in the slugs, there is, (as Cuvier has characteristically termed it), a *natural rupture*, through which the viscera are protruded into a conical bag twisted spirally. In this bag are contained the principal viscera, the liver occupying its extremity. The body of the animal is attached to the pillar of the shell by a complicated muscle, which shifts its place with the growth of the animal. The mouth is furnished above with a thin-arched corneous mandible, notched on the edges. The whole body, including the foot and head, are, in general, capable of being withdrawn into the cavity of the shell. In two genera the aperture is closed by a lid.

GENUS CYCLOSTOMA.—Aperture of the shell circular. The tentacula are linear and subretractile. The primary ones have subglobular, highly-polished extremities, considered by Montagu as the eyes. The true eyes, however, are placed at the exterior base of the large tentacula, and are elevated on tubercles, which are the rudiments of the second pair. The aperture of the pulmonary cavity is situated on the neck. The sexes are likewise separate; the penis of the male being large, flat, and muscular. The

Mollusca. mouth is formed into a kind of proboscis, and the upper lip is deeply emarginate.

GENUS *HELIX*.—Snail. Aperture of the shell lunulated; the width and length nearly equal. The snails differ from the slugs chiefly in the organs of reproduction. The vagina, previous to its termination in the sexual cavity, is joined by the canal of the vesicle, and by two ducts, each proceeding from a bundle of multifid vesicles. Each bundle consists of a stem or duct, and numerous branches, with blunt terminations. These organs secrete a thin milky fluid, the use of which is unknown.

Connected with the sexual cavity is the bag in which the darts are produced. The bag itself is muscular, with longitudinal grooves, and a glandular body at the extremity. This glandular body secretes the dart, which is in the form of a lengthened pyramid, consisting of calcareous filaments nearly resembling asbestos. Previous to the sexual union, the two snails touch each other repeatedly with the mouth and tentacula, and at last the dart of the one is pushed forth by its muscular bag, and directed against the body of the other, into which it enters, never penetrating through the integuments, and even, in many cases, falling short of its mark. Whether the use of the dart is merely to stimulate, or whether it is subservient to any other purpose, can scarcely be said to be determined.

The species belonging to this genus are numerous, and exhibit, in the form, the markings, and the coverings of the shell, numerous characters for their subdivision.

The species which are related to the *Turbo bidens per-versus* and *muscorum* of Linnæus, constitute a very natural family, which may be termed PUPADÆ, distinguished by the mouth being, in general, furnished with teeth, or testaceous laminæ, and the last whorl nearly the same as the preceding. Perhaps the most convenient way of dividing them is into two sections, the first including the dextral and the second the sinistral shells.

GENUS *VITRINA*.—Margin of the shield double. The upper fold of the shield is divided into several lobes, which are capable of being reflected over the surface of the shell. The shell itself is not capable of containing the whole body of the animal. The *Helix pellucida* of Müller is the type of the genus. It is a common British species, and was hastily regarded by Montagu as the fry of the *Helix lucida*.

GENUS *SUCCINEA*.—Termination of the pillar rounded. The mouth is large in proportion to the size of the shell, with the outer lip thin, and the pillar attenuated. The genus was first characterized by Draparnaud and named *SUCCINEA*. Afterwards Lamarck proposed the term *Amphibulina*, but latterly adopted that of Draparnaud. The name first employed indicates one of the most striking characters of the type of the genus; whereas the term *Amphibulina*, is founded on a mistake, and is apt to mislead. The *Helix succinea*, (the type of the genus), although found in damp places, is not amphibious. It never enters the water voluntarily. Indeed Müller says, "Sponte in aquam descendere numquam vidi, e contra quoties eum aquæ immisi, confestim egrediebatur." The same remark is made by Montagu, and we have often witnessed its truth.

ORDER II.—AQUATIC.

The aquatic pulmoniferous Gasteropoda have their residence constantly in the water. They possess two tentacula only. These are usually flattened, incapable of being withdrawn, and having the eyes at the internal base. The food consists of aquatic plants. Respiration can only take place at the surface of the water, to which the animals occasionally ascend, to expel from the pulmonary cavity the vitiated air, and replenish it with a fresh supply. The sexes are united. The spawn, which is in the form of a rounded gelatinous mass, containing many ova, is deposited on aquatic

plants under water. Previous to hatching, the foetus must be aerated by means of some branchial arrangement.

GENUS *LIMNEA*.—Aperture of the shell having the right lip joined to the left at the base, and folding back on the pillar.

The tentacula are lanceolated and depressed. The mouth is furnished with three jaws; the lateral ones simple; the upper one crescent-shaped, and emarginate. The male and female organs, though intimately connected internally, have their external orifices separated to a considerable distance, the former issuing under the right tentaculum, the latter at the pulmonary cavity. In consequence of this arrangement, the individuals of *L. stagnalis* have been observed by Geoffroy and Müller to unite together in a chain during coition, the first and last members of the series exercising only one of the sexual functions, the intervening individuals impregnating and receiving impregnation at the same time. Whether this is the constant or only accidental practice of this species, does not appear to be determined. We know that many other species of the genus are mutually impregnated, as usual, in pairs only.

The species of this genus are numerous. They reside in pools, lakes, and rivers, and furnish a favourite repast to the different kinds of trouts and water-fowl.

With regard to the *Limnea auricularia*, it would appear, from the observations of Draparnaud, (*Histoire des Mollusques*, p. 49,) that it exhibits a very singular structure of the respiratory organs. We shall quote his own words: "L'animal est pourvu de quatre filamens ou tubes qui partent de la partie supérieure du cou, près du manteau; ce sont des trachées. Ces tubes sont longs, blancs et très transparents, et on ne les distingue bien qu'à la loupe. Leur surface est comme rugueuse, et leur extrémité est un peu renflée. Ils sont rétractiles. L'animal les fait sortir à volonté, un, deux, trois ensemble: il les agite et les contourne sans cesse en divers sens: ce qui fait qu'on les prendroit pour de petits vers. Je présume que par ce mouvement ces organes séparent de l'eau l'air que y'est contenu et l'absorbent. Cet animal est très sujet, ainsi que les autres gastéropodes fluviatiles, à être infesté par le *nais vermicularis*, qui se loge ordinairement entre le cou et le manteau, au-dessous des tentacules, et s'agite sans cesse d'un mouvement vermiculaire." But little doubt, we think, can be entertained that this naturalist had been deceived by some of the parasitical leeches which infest the aquatic pulmonifera, and that, instead of breathing by means of tubular gills, the animal of the *L. auricularia* possesses, like those which it resembles in other characters, a pulmonary cavity.

GENUS *PHYSA*.—Pillar-lip destitute of a fold, and the whorls are sinistral. (*Zool. Journ.* vii. 363.) The external appearance of the animal is similar to the *Limnea*; but the margin of the cloak is loose, divided into lobes, and capable of being reflected over the surface of the shell near the mouth. This genus was instituted by Draparnaud. The *Bulla fontinalis* of British authors is regarded as the type of the genus.

GENUS *APLEXA*.—Pillar-lip, with a fold. This genus was instituted by us for the reception of the *Bulla hypnorum* and *rivalis* of British writers. The shell is more produced than in the *Physa*. The cloak of the animal is incapable of being reflected on the shell, and its margin is destitute of lobes.

GENUS *PLANORBIS*.—Cavity of the shell entire. This is another sinistral genus; the vent, pulmonary cavity, and sexual organs, being on the left, and the heart on the right side. The *P. corneus*, the type of the genus, pours forth, when irritated, a purple fluid from the sides, between the foot and the margin of the cloak.

GENUS *SEGMENTINA*.—Cavity of the shell divided. Externally, the shell appears similar to *Planorbis*; but internally, it is divided by testaceous, transverse partitions, into several chambers, which communicate with each other by

Mollusca. triradiated apertures. It is uncertain whether the animal is to be considered as dextral or sinistral. This genus was instituted by us several years ago, for the reception of the *Nautilus lacustris* of Lightfoot, first described and figured in *Phil. Trans.* vol. lxxvi. p. 160. tab. 1. f. 1, 8.

GENUS PERONIA.—The body is destitute of the external protection of a shell. The head is furnished with two long retractile tentacula. The snout is divided into two broad appendages. Between the tentacula, towards the right side, is the opening for the penis. The anus is terminal, immediately above which is the entrance to the pulmonary cavity; and on the right is the opening to the female organs, from which a groove runs towards the right lobe of the snout. The mouth is destitute of a proboscis or jaws. The tongue is merely a cartilaginous plate grooved transversely. The gullet is long in proportion, with a villous surface. There are three stomachs, each distinguished by its peculiar characters. The first is a true gizzard, covered internally with a cartilaginous cuticle, and its walls formed of two strong muscles, with connecting ligaments. The second stomach is funnel-shaped, with prominent ridges both on its external and internal surface. These ridges, at their origin internally, are highest, and project considerably into the cavity, acting like a valve in retarding the progress of the food. The third stomach is short and cylindrical, covered internally with equal longitudinal fine ridges. The intestine is nearly of equal thickness throughout, and upwards of twice the length of the body. The salivary glands are much branched, and pour their contents into the entrance of the gullet. The liver, in the animals of this genus, is distributed into three separate portions, each of which may be regarded as a distinct liver, an arrangement which is not known to take place in any other animal. The first liver is situate near the middle of the body, on the right side; while the second is placed near the posterior extremity. The ducts enter the cardiac opening of the stomach, each by a separate aperture, and seem to occupy the place of the zone of gastric glands observed in birds. The third liver is placed at the posterior end of the gizzard, into which it pours its contents by a short duct.

The most remarkable feature of the circulating system, is the position of the lungs at the posterior extremity of the body, which occasions a corresponding arrangement in the connecting organs. The entrance to the pulmonary cavity is immediately above the anus. The vessels in which the blood is aerated, are distributed on the roof and sides of the cavity. The pulmonic veins consist of two receptacles, one on each side, extending nearly the length of the body, which may be considered as *venæ cavæ*. These receive the blood by numerous vessels, and convey it directly to the lungs. The aerated blood is conveyed by a systemic vein into a large auricle, seated in front of the lungs, of considerable size, with the walls fortified on the interior by branched ligaments. The ventricle is placed at its anterior extremity, and separated by two valves. The aorta arises from the opposite side of the ventricle, its main trunk passing on towards the head.

The male and female organs of generation, although occurring in the same individual, appear to occupy different parts of the body. The opening of the male organs is at the tentacula, which leads to a cavity terminating in two unequal recesses. The anterior is the smallest, and receives the termination of a vessel three or four times longer than the body, which takes its rise at the external base of the cavity, apparently from the cellular substance, and, after a variety of convolutions in the neighbourhood of the mouth, opens into the recess. The second recess is the largest, and the vessel connected with it is most complicated. Its origin is in a mass, which occupies a considerable portion of the abdominal cavity, and which consists of a vessel forming a great number of complicated convolutions, liberally supplied

with bloodvessels. The duct proceeds from this mass, undergoes for a short space a sudden thickening of its walls, after which it again contracts, and, before it terminates in a perforated glandular knob in the recess, it contains a pedunculated fleshy body, with a sharp-pointed corneous extremity, probably capable of being protruded into the recess and cavity. The parts which are considered as forming the female organs, or those which are connected with the sexual cavity on the right side of the anus, consist of an ovarium, divided into two lobes, each of which may be perceived to be again minutely subdivided. The oviduct is tortuous, and passes through a glandular body, which, in the other gasteropoda, is regarded as the testicle. The pedunculated vesicle gives out two ducts, one of which goes to the testicle, the other to the uterus. It is difficult to form even a conjecture regarding the uses of all this complicated sexual apparatus. The subject can only be elucidated by an attentive examination of the condition of the organs at different seasons of the year, and by studying, at the same time, the habits of the animals.

The preceding description of the characters of the genus is taken from the anatomical details of a species found creeping upon the rocks under water in the Mauritius, by M. Peron, which Cuvier referred to the genus *Onchidium* of Buchanan, already noticed. We have ventured to institute the genus, and to name it in honour of the discoverer of the first ascertained species. Cuvier conjectures that it breathes free air, and has accordingly inserted it among the *pulmones aquatique*. Some doubts, however, may reasonably be entertained as to the truth of this supposition. It would certainly be an unexpected occurrence, to find a marine gasteropodous mollusca obliged to come to the surface, at intervals, to respire. It will probably be found that it is truly branchiferous.

CLASS II.—BRANCHIFERA.

The molluscos animals of this class are more numerous than those of the preceding. They chiefly inhabit the waters of the ocean, a few genera only being met with in fresh water lakes and rivers. The branchiæ which constitute their aerating organs, exhibit numerous varieties of form, position, and protection, and furnish valuable characters for their methodical distribution.

ORDER I.—BRANCHIÆ EXTERNAL.

The branchiæ are pedunculated, and more or less plumose. They are moveable at the will of the animal, and, in general, are capable of great alteration of form.

GENUS DORIS.—Oral tentacula two; vent without scales. The cloak is covered with retractile papillæ, and separated from the foot by a distinct duplicature. Towards its anterior margin are placed the two superior tentacula. These are retractile, surrounded at the base with a short sheath, and supported on a slender stem, having an enlarged compound plicated summit. The neck is short, and above the mouth there is a small projecting membrane, connected at each side with the oral tentacula, which are in general minute, and of difficult detection. The mouth is in the form of a short trunk, leading to fleshy lips, within which the tongue is placed. This last organ is covered with minute reflected hairs, and, from its motion, appears to be destined exclusively for deglutition. The gullet is a simple membranaceous tube, terminating in a stomach, which presents on the interior a few longitudinal folds. It is furnished with a small cæcum, the extremity of which receives the bile from the liver. The stomach likewise receives the secretion of another gland, which is not connected with the liver, in the form of a small bag, the inner surface of which is covered with numerous papillæ. The intestine is lodged in a groove on the surface of the liver, and proceeds directly to the anus. The liver itself is divided into two lobes, and gives

Mollusca. rise to numerous biliary ducts, which proceed to the stomach. But it likewise gives rise to a duct which proceeds to a small bag plaited on the inside, and afterwards opens on the surface at a small hole near the anus. It yet remains to be determined, whether the fluid carried off by this conduit be excrementitious matter, separated by the liver, or whether the gland which produces it be distinct from that organ, but so interwoven therewith as to elude the observation of the anatomist.

It is obvious, from the structure of the digestive organs, that the species subsist on soft food, requiring neither cutting nor grinding, and in this respect, differ remarkably from the species of the genus *Tritonia*, which were formerly arranged along with them.

The organs of generation differ little from the other hermaphrodite gasteropoda. The vesicle furnishes two canals, one of which goes to the testicle, the other to the penis. There is likewise a minute bag connected with the canal of the latter. The spawn is deposited on sea-weeds and stones. It is gelatinous, of a white colour, and in appearance resembles the sponge denominated *Grantia compressa*.

GENUS TRITONIA.—Branchiæ destitute of basilar sheaths. The branchiæ are in the form of plumes, or imbricated productions, placed in a row on each side the back. The tentacula, which are partially retractile, have a sheath at the base. In some of the species there are indications of eyes. The mouth consists of two lips, which are placed longitudinally, and open into a short canal. The jaws consist of two corneous plates, united at the upper dorsal edge, slightly arched, and meeting at their upper margin, for the purpose of cutting. Within these is the tongue, which differs remarkably from the same member in the *doris*. In the latter, the spines with which it is beset are reflected, and draw the food to the gullet, while in the former, the spines are deflected, and serve to keep the food within the reach of the jaws. The tongue of the *doris*, therefore, serves for deglutition, that of the *tritonia* for mastication. M. Cuvier describes the functions of both as similar. The salivary glands are placed on each side the gullet, and empty their contents behind the jaws. The gullet has a few longitudinal folds; the stomach is simple, scarcely differing from the gullet; and the intestine proceeds almost directly to the anus, situate on the right side. The liver is small, and situate behind, enveloping the stomach, and intimately united with the ovarium. The organs of generation exhibit nothing remarkable. The pedunculated vesicle has a simple canal. The external opening of the organs of generation is situate a little before and beneath the anus. The *T. Hombergii arborescens*, *pinnatifida*, and *bifida*, are examples of British species.

GENUS SCYLLEA.—Branchiæ seated dorsally on the fins. Tentacula two. On each side of the back are two membranaceous expansions, and one on the tail, supporting on their dorsal surface scattered plumose branchiæ. Each of the tentacula is furnished with a large funnel-shaped sheath. The foot is very narrow, with a mesial groove, used in climbing up the stalks of sea-weeds. The mouth is placed at the base of the tentacula, and surrounded with a semicircular lip. The tongue is in the form of a tubercle, with reflected points. The gullet is plaited longitudinally. The stomach is short and cylindrical, with a ring of hard, longitudinal scales. The liver consists of six unequal globules, and the bile is poured into the cardiac extremity of the gullet. The *Scyllea pelagica* has been long known to naturalists, and appears to be very common in the equatorial seas, adhering to the stems of the *Fucus natans*.

GENUS THETHYS.—Branchiæ forming a row on each side of the back, consisting of fringed processes, alternately larger and smaller. The body is ovate, with the cloak and foot continuous. The neck is distinct from the foot, and is narrow. Above, the neck is continuous with the cloak, from

which arises a large semicircular expansion, used probably as a fin. The margin of this expansion is fringed with numerous filaments, and on the upper surface, within the border, is a row of conical tubercles. The true tentacula are placed towards the base of this fin near the neck. Each of them consists of a small fleshy cone, striated across, with a semicircular sheath behind. The branchiæ consist of a tapering, fleshy stalk, spirally twisted towards the summit with a series of filaments on one side. They are fourteen in number on each side, alternately and oppositely small and large. The anus opens in front of the third branchia on the right side. The orifice of generation is exhibited under the first branchia of the same side. In front of each of the larger branchiæ, is a small cavity with a small filament in the centre. The mouth is situate underneath the tentacula. It consists of a large funnel, covered within with soft papillæ, destitute of jaws or tongue. The gullet is short, the stomach simple, fleshy, and covered with a thick cuticle. The salivary glands are slender and branched, and open into the gullet. The intestine is likewise short, and proceeds directly to the anus. The liver pours the bile into the canal at the pylorus; and likewise sends out another duct, which opens externally near the anus. The organs of generation are similar to the *Doris*. The *T. fimbria* is the type of the genus, a figure of which, with its anatomical details, is given by M. Cuvier, in his *Mémoire sur le Genre Thetys*.

GENUS VALVATA.—In this genus are included several species which resemble in aspect the aquatic pulmoniferous gasteropoda. The branchiæ appear in the form of a feather, with a central stem, and a row of compound branches on each side, decreasing in size from the base to the free extremity. This stem issues from the neck near the middle, a short way behind the anterior tentacula. Near this plume, but towards the right side, is a single simple filament, like a tentaculum. The anterior tentacula occupy the usual position, are setaceous, and have the eyes placed at the base behind. The spiral shell is capable of containing the body, and the aperture can be closed by a spirally striated operculum attached to the foot. The internal structure is unknown.

GENUS PATELLA.—Shell entire. Mouth with tentacula. This genus differs from the others of the order to which it belongs. The back is covered by a conical shell, within the cavity of which the animal is capable of withdrawing itself. The cloak is large, covering both the head and foot. It is united with the shell along its superior margin. The foot is fleshy, and furnished with numerous muscular filaments, which unite, in the superior part of the cloak, to form a strong muscle, by which the body adheres to the shell. The action of this muscle brings the shell close to the surface to which the foot adheres, or removes it to a distance. The head is furnished with a large, fleshy snout, supporting at the base two pointed tentacula. The eyes are placed on a small elevation at the external base of the tentacula. A little way behind the head, and below the cloak, on the right side, are two apertures, being the anus and orifice of generation. The gills occupy the same position as in the preceding genera. In some, the branchiæ form a complete circle; in others, the circle is interrupted anteriorly at the head.

Within the trunk, the mouth is fortified by two cartilaginous cheeks, which, at their union anteriorly, support the base of the tongue. This last is a most singular organ. It is longer than the whole body, narrow, and covered with three rows of short reflected spines, interrupted longitudinally and transversely. Its fixed end only can be exercised in deglutition, its free end being coiled up the abdomen. On the upper side of the mouth is a semicircular osseous plate, or upper jaw. The gullet is furnished with a dilatable pharynx. The stomach is elliptical, with the cardia and pylorus at opposite extremities. The intestines are

Mollusca. variously folded, and are several times longer than the body. The salivary glands are minute. The liver is intimately united with the stomach and intestines. The heart is situated on the left side, in the anterior part of the body. The auricle receives the aërated blood from one vein when the circle of the gills is complete, and by two when interrupted. This auricle is placed on the anterior side of the heart. An aorta arises from each side, to convey the blood to the body. The ovarium is placed underneath the liver; and, as it exhibits some differences of organization, M. Cuvier infers that it likewise contains the male organs. The species belonging to this genus are numerous, and appear to admit of distribution into sections; the first having the branchial circle complete, the second interrupted.

GENUS CHITON.—Shell constituting a series of imbricated dorsal plates. The body is elliptical. The cloak is firm and cartilaginous, and variously marked on the margin. The dorsal plates are arched, and occupy the middle and sides of the back, where they are implanted in the cloak, in an imbricated manner, the posterior margin of the first valve covering the anterior margin of the second. The foot is narrow. The mouth is surrounded with a semicircular curled membrane, and is destitute of tentacula. The anus consists of a short tube, placed at the posterior extremity of the cloak. The external orifice of generation has not been detected.

The mouth is capable of forming a short proboscis. The tongue is short, and armed with strong, reflected spines. The gullet is short, and the stomach, which is lengthened and folded, is membranaceous. The intestine is several times longer than the body, and much folded. The liver is divided into numerous lobes, and intimately united with the stomach and intestines. The heart is situated at the posterior part of the body. The auricle is placed posteriorly, and receives the aërated blood from two veins. Each vein descends along the base of the gills, collecting the aërated blood from the particular side of the body to which it belongs; and, what is most remarkable, when opposite the ventricle, it is suddenly enlarged, and sends off a branch which communicates with it, and again contracts and unites with its fellow from the opposite side, to form the auricle. A single aorta arises from the anterior side. The ovarium is conical, and divided into numerous lobes. Behind, two ducts seem to arise, and to proceed one to each side; but it has not been determined whether they open externally. No male organs have been detected; nor is there any thing accurately known with regard to the peculiar nature of their hermaphroditism.

GENUS PHYLLIDIA.—Anus placed dorsally near the extremity of the cloak. The body, in the animals of this genus, is ovate. The foot is narrow in front. The cloak is broad, coriaceous, and destitute of a shell. Towards its anterior extremity are two cavities, from which issue the retractile superior tentacula, as in the genus *Doris*. Nearly at the posterior extremity is another cavity, containing the anus. This opening, though similar in situation to that of the *Doris*, is merely a short simple tube. The head is immediately above the anterior margin of the foot, above which is the mouth, having a small conical feeler on each side. Under the margin of the cloak on the right side, and about half way between the mouth and the middle of the body, are two openings, in a tubercle, for the organs of generation. The branchiæ consist of slender complicated leaves, which surround the body between the foot and the cloak. The circle is interrupted at the head and at the tubercle of generation. The mouth is destitute of jaws. The gullet is simple, ending in a membranaceous stomach. The pylorus is placed near the cardia, and the intestine goes directly to the anus. The salivary glands are small, and placed near the mouth. The liver is large in proportion. The heart is situated in the middle of the back. The auricle is simple,

placed on the side next the tail, and supplied by the two systemic veins which collect the aërated blood from the branchiæ on each side. There is a simple aorta arising from the opposite side of the heart. The organs of generation appear to be similar to those of the preceding class; but they have not as yet been minutely examined. The existence of eyes is not satisfactorily determined. The animals of this genus appear to be inhabitants of the tropical seas. Cuvier has given descriptions and figures of three species, which differ remarkably from one another in the protuberances of the cloak.

GENUS APLYSIA.—Branchiæ with a corneous lid. The body of the *Aplysia* is ovate, acuminate behind, and produced before to form a neck. The foot is narrower than the body. In the middle of the back is a corneous plate inclosed in a bag in the skin, and on each side, and behind, there is a fold by which this part may be concealed. The head is slightly emarginate, with a feeler on each side. The superior feelers are situated on the neck. In front of each of these is a small black point or eye. The branchiæ are situated underneath the dorsal plate, on the right side, and exhibit a complicated plumose ridge, capable of expansion beyond the edge of the plate. The anus is situated immediately behind the branchiæ, and before these is the orifice of generation, from which proceeds a groove along the neck to the inferior base of the fore feeler, on the right side, where there is an opening for the penis. Within the longitudinal lips there are two smooth, corneous plates, the substitutes for jaws; the tongue is rough, as in many of the other gasteropoda. The gullet is short, and suddenly expands into a large subspirial crop, with membranaceous walls. To this, a gizzard with muscular walls succeeds, the interior of which is armed with numerous pyramidal teeth, with irregular summits, of a cartilaginous nature. The connection between these teeth and the integuments is so slender, that they are displaced by the application of the smallest force. They, however, project so far into the cavity, as to offer resistance to the progress of the food. There is yet another stomach, armed on the one side with deflected, pointed, cartilaginous teeth. At the pyloric extremity are two membranaceous ridges, between which are biliary orifices, and the opening into a long narrow cæcum, with simple walls, which is contained within the liver. The intestine is simple, and after two turns ends in a rectum. The salivary glands are very long, and, as usual, empty their contents into the pharynx. The liver is divided into three portions by the folds of the intestine, each of which consists of several lobes. The biliary vessels are very large, and open at the mouth of the cæcum into the last stomach. The food of the *Aplysia* consists of sea-weeds and minute shells.

The circulating organs are remarkable. On each side the body, in the region of the dorsal plate, there is a large vessel, which receives blood from different parts of the body, and which likewise, by various openings, has a free communication with the cavity of the abdomen. In this respect there is a resemblance to the spongy, glandular bodies of the *venæ cavæ* of the *Cephalopoda*. These two vessels, or *venæ cavæ*, unite posteriorly, and transmit their contents to the gills. The aërated blood is now conveyed to an auricle, of large dimensions, and uncommonly thin walls, situated beneath and towards the front of the dorsal plate, and emptying its contents through a valve, into the right side of the ventricle. The aorta, which issues from the left and anterior side, divides into two branches, the smallest of which proceeds to the liver on the left. The larger branch is again divided, the smaller branch proceeding to the stomach. The largest trunk that remains, before it leaves the pericardium, has two singular bodies attached to it, consisting of comparatively large vessels, opening from this aortic branch. The use of these glands is unknown. The organs of generation likewise exhibit some remarkable peculiarities. The

Mollusca. ovarium is situate in the posterior part of the abdomen. The oviduct is tortuous in its course, passes along the surface of the testicle, and, after uniting with a clavate appendage, opens into a common canal. The testicle is firm, apparently homogeneous in its texture, of a yellow colour, with spiral ridges on its surface. The vas deferens arises from a complex, glandular body, and unites with the common canal. This common duct, before it reaches the external orifice, receives the contents of the pedunculated vesicle, and has attached to it a botryoidal, glandular organ, the use of which is unknown, but which some suppose to be employed to secrete an acrid liquor regarded as venomous. It is obvious from this structure, that the seminal fluid and eggs must come in contact in the common canal, and at the single orifice, provided they are both ejected at the same time. From the orifice to the right fore-feeler there is a sulcus, leading to the pore containing the retractile penis. This organ, like those of the other mollusca, is solid. It terminates in a small filament. The external groove is the only connection between it and the other sexual organs.

There is a peculiar secretion of a purple fluid which here deserves to be recorded. It issues from a spongy texture, underneath the free side of the dorsal plate. Connected with this cellular reservoir is a glandular body of a considerable size, which is supposed to secrete the coloured fluid. This gland is supplied by a large branch of the glandular aorta, and gives out two very large veins to the left vena cava. The fluid itself has never been carefully investigated. It is not altered by the air after drying, nor is its colour destroyed by acids or alkalies, although the tint is a little changed, and rendered less pure. Both these reagents precipitate white flakes from the fluid. This liquor is poured out by the animal when in danger or constrained, and colours the water for several yards around. It ejects it readily when put in fresh water; and when entangled in a net, several yards of it in the neighbourhood are sometimes stained, greatly to the amazement of the unsuspecting fishermen.

The *Aplysia* has been long known in the records of superstition under the name of the *Sea Hare*. Its flesh, and the inky fluid it pours out, have been regarded as deleterious to the human frame. Even to touch it was supposed to occasion the loss of the hair; while the sight of it would not fail to subdue the obstinacy of concealed pregnancy. The progress of science has exposed the errors, or perhaps tricks, of the earlier observers, and proved the innocence of an animal formerly invested with every repulsive and noxious attribute. The *A. depilans*, the type of the genus, is of frequent occurrence on the British shores. The *A. punctata* of Cuvier may be regarded merely as a variety.

GENUS DOLABELLA.—Dorsal plate a solid shell.

This genus differs from *Aplysia*, in the dorsal plate being calcareous and hard. The fore part of the body is narrow; behind it is larger, and obliquely truncated. The disc thus formed is circular, surrounded with a fringe of fleshy filaments. From the centre of this disc, a longitudinal slit extends forward, a little way beyond the anterior margin, and contains the branchiæ. The position and structure of the other organs are precisely similar to those of the *Aplysia*. This genus was instituted by Lamarck, from characters derived exclusively from the dorsal plate or shell. Cuvier afterwards examined a species brought from the Mauritius by Peron, which he considers as the one figured by Rumphius in his *Amboinshe Rariteitkamer*, tab. x. No. 6, and which he has consecrated to his memory, naming it *Dolabella* Rumphii.

GENUS PLEUROBRANCHUS.—Tentacula two in number. Cloak and foot expanded, between which, on the middle of the right side, the branchiæ are placed. The cloak is strengthened in the middle, above the branchiæ, by a thin expanded subspiral shell. The neck is short, and in some contracted, with the front emarginate, exhibiting the com-

mencement of the inferior tentacula. The upper tentacula are tubular and cloven. The gills occur at the edge of the dorsal plate. In front of these are the orifices of the organs of generation, and the anus is situate immediately behind the gills. The mouth is furnished with a short retractile proboscis. The tongue occupies both sides of the mouth, and is covered with spines. The gullet is enlarged into a kind of crop before it enters the stomach; this is folded, and is divided by contractions into three parts. The first stomach has muscular walls of moderate thickness, with a single longitudinal band. The second has membranaceous walls, with longitudinal internal ridges, and the third has thin and simple walls. The gut is short. The salivary glands are situate at the folds of the stomach, and by two canals empty their contents into the mouth. The liver is placed on the stomach, and empties itself into the lower part of the crop. The heart is nearly in the middle of the back. Its auricle is on the right side, at the base of the branchiæ; and the ventricle sends out at the opposite side three arteries.

M. Cuvier has figured and described the *P. Peronii* with its anatomical details. Two species likewise appear to be known as natives of the British seas.

GENUS BULLA.—The head is destitute of tentacula and the body of the animal, protected by a convoluted shell, is oblong, becoming a little narrower in front. Below, the foot is broad, thin, and waved on the margin, expanded on each side behind, and capable of being turned upwards. At the posterior part of the foot, but separated from it by a groove, there is a broad, membranaceous appendage, a part of which is folded upwards, and a part spread over bodies, like the foot. It assists in closing the mouth of the shell, and in its position and use is analogous to the operculum, in the following order. Above the foot, in front, also, but separated from it by a groove, there is a fat, fleshy expansion, which Cuvier terms the tentacular disc, considering it as formed by the union of the inferior and superior tentacula. In the centre of the disc, in the *Bulla hydatis*, (*Lin. Trans.*, vol. ix. tab. 6, f. 4), Montagu observed two eyes. Between this portion of the back and the posterior extremity, is the dorsal plate or shell, forming the genus *Bulla* of conchologists. In some species, this shell is covered by the integuments, while in others it is exposed. But in all, the part containing it is partially concealed by the animal, by means of the reflected margins of the foot, and its appendage. Along the right side of the body there is a groove, formed by the foot and its appendage, on one side, and the dorsal plate and tentacular disc on the other. The branchiæ are situate in a cavity under the shell or dorsal plate, and resemble those of the *Aplysia*. Behind the gills, in the lateral groove, is the anus; and in front of these, the orifice of the united organs of generation. The penis is removed as in the *Aplysia*, and connected by a similar slit.

The mouth is, as usual, in front, above the foot and beneath the tentacular disc, both of which serve as lips. The cheeks are strengthened on each side by a corneous plate. The tongue is well developed in some, as the *B. ampulla*, while in the *B. aperta* it is reduced to a small tubercle. The gullet is large, and in the *B. lignaria* makes two folds before entering the gizzard. This last organ is fortified by three testaceous plates, convex and rough on the inner surface, and attached to strong, muscular walls. These plates exhibit in the different species considerable varieties of form and markings. The intestine, before terminating in the anus, makes several convolutions in the substance of the liver. The salivary glands exhibit considerable differences. In the *B. ampulla* they are long and narrow, and their inferior extremity fixed to the gizzard. In the *B. aperta* and *B. lignaria*, they are short, with the extremity free. In the *B. hydatis* they are long, unequal, and the extremity of the one, belonging to the left side, is forked. The liver forms a part of the contents inclosed in the spire of the shell. It

Mollusca. envelopes the intestine, and empties the bile into its pyloric extremity. The auricle and ventricle appear to occupy the same relative position as in the *Aplysia*, but the structure of the arteries is unknown. The organs of generation have also so near a resemblance as to forbid a detailed description. Some species are said to eject a coloured fluid, like the *Aplysia*, from the lid of the branchiæ. A gland is observed in the *Bulla lignaria*, similar to the *Aplysia*, in which it is probable the fluid is prepared.

The species of this genus have not been sufficiently investigated in a living state. When preserved in spirits, it is impossible to form a correct idea of their true appearance, as exhibited when alive in sea-water, since they usually exist as a shapeless mass. Cuvier has given delineations of such preserved species, but they bear no resemblance to the figures of Montagu, of the same species, taken from living objects. M. Lamarck is inclined to divide the genus into two, distinguishing those who have the shell concealed, by the term *Bullea*, from such as have the shell in part exposed, which he retains in the genus *Bulla*. The shells of the genus *Bullea* are thin and white, as *B. aperta*; those of *Bulla* stronger, more opaque, and covered with an epidermis, which, after the death of the animal, is easily detached, as *B. lignaria*.

GENUS DORIDIUM (of Meckel). Destitute of a dorsal plate or shell. There is a cavity in the cloak, with a spiral turn. The branchiæ, and accompanying organs, are placed far behind. There is here no appearance of a spinous tongue; the gullet is simple, and the stomach is membranaceous. *D. carnosum*, a native of the Mediterranean, is the type of the genus.

ORDER II.—BRANCHIÆ INTERNAL.

The aërating organs are contained in a cavity, and appear in the form of sessile, pectinated ridges.

1st Subdivision.

Heart entire, and detached from the rectum.

This group, forming the *Pectinibranchia* of Cuvier, includes nearly all the marine Gasteropoda, which have spiral univalve shells. It likewise contains a few species which inhabit the fresh water.

The foot is usually fortified above, on its posterior extremity, with a corneous plate, which acts as a lid to the shell, when the animal is withdrawn into the cavity. The anterior extremity is in some of the species double. The anterior margin of the cloak forms a thick band, or arch, rising from the foot, behind which is the portion of the body that is always contained in the shell, and which is covered with a very thin skin. Between the margin of the cloak and foot is situate the head, supported on a short neck. The tentacula are two in number, bearing eyes at their base, or on short lateral processes, which have some claims to be considered as tentacula. The hood is frequently emarginate, and sometimes fringed. The mouth is more or less in the form of a proboscis, in some cases armed within with spinous lips, or furnished with a long narrow spiral tongue, armed with spines, as in the common periwinkle. The nature of this kind of tongue, the spiral extremity of which is free and lodged in the abdomen, is not well understood.

The entry to the gills is by a large aperture between the margin of the cloak and neck, at the middle, or towards the right side. These are contained in a cavity on the back of the animal, and consist of leaves arranged in one or more rows, which adhere to the walls of the cavity. At the entrance of this cavity is the anus and oviduct. The male and female organs are considered not only as distinct, but as occurring on different individuals. The evidence in support of this opinion is in many cases complete. The penis is in some external, and incapable of being withdrawn, while in others it is retractile, and situate in a cavity in the right ten-

taculum. The body of the animal is attached to the shell by means of two muscles, which adhere to the pillar near the same place, and shift their position, by an arrangement not well understood, in proportion as the individual increases in size. These muscles terminate in the foot and mouth.

The animals of this order have not been examined sufficiently in detail, to admit of their distribution into natural groups, distinguished by characters founded on important differences of organization. The form of the shell has been resorted to, with the view of assisting arrangement. The characters thus furnished would be useful and valuable, were they the index of any peculiar internal structure. But, unfortunately, animals widely different in structure inhabit shells of the same form, and *vice versa*, so that, however useful the mere conchologist may find the form of the shell to be in his arrangements, it can only be regarded by the zoologist as occupying a subordinate place. Without, therefore, entering into any details regarding the structure of the few species which have been examined anatomically, we shall merely point out the tribes and families which have been contemplated, the characters of which in a great measure depend on the shape of the shell.

1st Tribe.

Shell external.

The shelly covering exhibits all the variations of the spiral form. The internal structure has hitherto been in a great measure neglected, so that the characters employed in the methodical distribution of the species and genera are derived from the shelly appendage of the cloak. The groups, therefore, are merely artificial, temporary combinations, to a very few of which only we shall make reference.

GENUS JANTHINA.—Foot with an adhering spongy body. In this genus, represented by the *Helix janthina* of Linnaeus, the spongy body is capable of changing its dimensions, and enabling the animal to sink or rise in the water at pleasure. When irritated, the animal ejects a purple fluid from the cellular margin of the cloak above the gills, not unlike the *Aplysia*. This species was added to the British Fauna by the late Miss Hutchins.

GENUS VELUTINA.—Foot simple. This genus was formed by us for the reception of the *Bulla velutina* of Müller, (*Zool. Dan.* tab. ci. f. 1, 2, 3, 4), the *Helix lævigata* of British writers. The foot is destitute of lid or appendage, and is broad before, and pointed behind. The tentacula are two in number, short and filiform, with eyes at their external base. The head is broad and short. In addition to these characters given by Müller, we have been enabled to add the following, from a specimen, somewhat altered, which was found in the stomach of a cod-fish. The animal adheres to the shell by two linear muscles, one on each side the cloak. The branchial cavity is towards the left side. The tongue is spinous, narrow, with its free extremity spiral. Eyes rather behind the tentacula. Penis exerted on the right side of the neck, immediately behind the eye. Cloak large in proportion to the size of the foot. We have termed the genus *Velutina*, bestowing on the species the trivial name *vulgaris*.

In the following groups the anterior margin of the aperture of the shell is canaliculated. This groove in the aperture of the shell is produced by the anterior margin of the cloak being extended over the opening into the gills, for the purpose of acting like a tube or syphon, in conveying the water to and from the branchial cavity. The species are considered as oviparous, with distinct sexes in separate individuals.

1. *Shell convoluted*.—The shell has an oval or linear mouth parallel with its length. The whorls, which are small segments of large circles, are wrapped round the pillar, and the one rising a little above the other, embrace or inclose the preceding ones. The four following families appear to belong to this division.

Mollusca. Family 1. *Conusidae*.—Furnished with a long proboscis, and produced tentacula, with the eyes near the summit on the outside. The lid is placed obliquely on the foot, and is too small to fill the mouth of the shell. The genera *Conus* and *Terebellum* form this family.

Family 2. *Cypreadae*.—Cloak enlarged, and capable of folding over the shell. There is no lid. The genus *Cyprea* is the type.

Family 3. *Ovuladae*.—Both extremities of the aperture canaliculated. The inhabitants of all the genera, *Ovula*, *Calpurnia*, and *Volva*, are unknown. The last genus includes the *Bulla patula* of Pennant.

Family 4. *Volutadae*.—Canal of the aperture abbreviated. Pillar-lip plaited. The foot appears to be destitute of a lid. The genera are numerous; *Voluta*, *Oliva*, *Cymbium*, *Margarella*, *Cancellaria*, *Mitra*, *Ancilla*, *Volvaria*, and *Tornatella*. The last genus contains the *Voluta tornatilis* of British writers.

2. *Shell turreted*.—The whorls of the shell, the revolving spire of which is subconical, scarcely embrace one another, but are merely united at the margins. Three families may here be established.

Family 1. *Buccinidae*.—Canal short, scarcely produced beyond the anterior margin of the lip, and bent towards the right. The tentacula are remote, and the head is destitute of a hood. The mouth has a retractile proboscis. The following genera belong to this family: *Buccinum*, *Eburna*, *Dolium*, *Harpa*, *Nassa*, *Purpura*, *Cassis*, *Morio*, *Ricinula*, and *Monoceros*.

Family 2. *Muricidae*.—Canal produced, and straight. The tentacula approach the head and mouth as in the preceding family. The genera are *Murex*, *Typhis*, *Ranella*, *Fusus*, *Pleurotoma*, *Pyrula*, *Fasciolaria*, *Terebra*, *Tritonalia*, and *Turbinella*.

Family 3. *Cerithiidae*.—Canal short and recurved. Head with a hood. This family contains the marine *Cerithium* and *Strutheolaria*, and the fluviatile *Potamidum*, *Melanopsis*, and *Pirena*.

Family 4. *Strombusidae*.—Canal short, and bent towards the right. The outer margin of the aperture becomes palmated with age, and exhibits a second canal, generally near the former, for the passage of the head. The following are the genera: *Strombus*, *Pterocera*, *Hippocrenes*, and *Rostellaria*.

2d Tribe.

Shell internal.

This tribe consists at present of only one genus, termed *Sigaretus*, two species of which are natives of Britain. The foot of the animals belonging to this genus, or rather of the species which constitutes the type, is oval, with a duplication in front. The cloak is broad, with an indentation on the left side, in front, leading to the branchial cavity. A ring of transverse muscles unites the cloak with the foot. On the back is placed the shell, which does not appear on the outside, as it is covered by a thick cuticle. It is lodged in a sac, and united by a muscle, which adheres to the pillar. The hood is produced, at each side, into a flattened tentaculum, with an eye at the external base. The anus is situate at the branchial indentation on the left side. The penis is situate on the right side of the neck; it is external, with a crooked, blunt, lateral process near its extremity.

The mouth is in the form of a short proboscis. The tongue is armed with spines, and is long and spirally folded. The salivary glands are large. The stomach is membranaceous, giving off the intestine near the cardia. The intestine makes two folds. The liver, with the testicle in the male, and the ovary in the female, occupy the posterior part of the body, under the spire of the shell.

2d Subdivision.

Heart traversed by the rectum.

This group includes the order *Scutibranchia* of Cuvier.

In general form, and in the structure and position of the branchiae, the resemblance to the genera of the preceding subdivision is very great. The animals differ, however, in many particulars. The heart is furnished with two auricles, and is perforated by the intestine. The sexes appear to be incorporated in the same individual, or rather the male organs are unknown. The body is protected by a shell, the aperture of which is wide, and never closed by a lid.

1st Tribe.

Shell ear-shaped, flat, with a lateral, and nearly concealed spire.

Family *Haliotidae*.—The genera of this group exhibit well-marked characters in the shell. In the *Haliotis*, the left margin of the shell is pierced by a row of holes. In *Padola* these holes are nearly obliterated; but there is an internal groove and external ridge in the line of their direction. In *Stomatia*, there are neither holes nor ridges. In the *Halyotis*, the foot is oval and large. The sides of the body, all round, are ornamented with one or more rows of simple or branched filaments. The shell is placed on the back with the spiral part behind, and the row of holes on the left side, through which some of the filaments are protruded. The animal is attached to the shell by a single large muscle. The entry to the branchial cavity, which likewise contains the termination of the rectum and oviduct, is on the back. The gills are in two ridges, consisting of complicated branched filaments. At the entrance of the cavity, the cloak is furnished with a slit, the left margin of which rests upon the pillar of the shell. The edges of this slit are furnished with filaments, which pass through the anterior holes of the shell. The use of this singular arrangement is unknown. The branchial cavity likewise contains the viscous organ, in common with the *Pectinibranchiae*.

The hood is emarginate, with a long tentaculum on each side, behind which, towards the side, is a cylindrical protuberance, bearing the eye at the top. The mouth is in the form of a short proboscis, with two corneous plates as cheeks, and a long narrow tongue extending backwards, and covered with spines. The pharynx is dilatable, with internal folds. The salivary glands are very small. The gullet is very short. The stomach is divided into two portions, the first of which is striated longitudinally with a glandular structure, and receives a biliary duct. The second is separated from the former by a valve, is smaller, with transverse striae, and a double ridge. It likewise receives bile through two apertures. There is another valve at the pylorus; and the intestine, after making some turns, is surrounded by the heart. There is an auricle on each side, receiving the aerated blood from each of the gills.

2d Tribe.

Shell conical, simple, or slightly revolute at the apex.

A. Cavity of the shell interrupted by a testaceous plate. This division consists of five genera, each of which may be regarded as the type of a family, although, for the present, they are all included in one. In the *Crepidula*, the gills form a transverse ridge on the roof of the cavity, consisting of filaments extending beyond the margin. The eyes are at the base of the tentacula. There is only one fluviatile genus, termed *Navicella*.

B. Cavity of the shell entire.

In the *Capulus*, the shell is entire, the foot is complicated on its anterior margin. The shell adheres to the animal by a circular muscle, leaving an opening in front, for the issue of the head and entrance to the branchial cavity. The gills form a single ridge across the roof. The mouth is in the form of an extended proboscis, with a deep groove above. The tentacula, which are two in number, have the eyes at the external base. The anus is on the right side of the branchial cavity. In the *Carinaria*, the foot appears to be compressed, and formed for swimming. The head is covered with a group of tubercles. The mouth is furnished

Mollusca. with a proboscis. Near the middle of the body the shell is attached. The surface of the body above is closely covered with small tubercles. It is probable that the species here alluded to is the same with the *Pterotrachea coronata* of Foraskæl.

Fissurelladæ. Shell with a slit or perforation. In the *Fissurella*, the apex of the shell is perforated, and united to the cloak by a circular muscle open in front. The cloak forms a duplicature in front for the branchial cavity, which extends to the perforated apex of the shell. The gills consist of two ridges; at the dorsal extremity of which is the anus. It is probable that the excrements are ejected at the perforation in the apex of the shell, and likewise the water which enters the branchial cavity in front. The head is furnished with two tentacula, bearing the eyes at the external base. The *Patella græca* and *apertura* may be quoted as British examples of the genus.

The genus *Emarginula* differs from the former in the apex of the shell not being perforated. Its place, however, is supplied by a slit on the anterior margin, which is the entrance to the branchiæ and anus. The foot is surrounded with a row of filaments, and the eyes are supported on short footstalks, characters in which it approaches the genus *Hal-yotis*. The *Patella fissura* of conchologists is considered as the type of the genus.

DIVISION II.—MOLLUSCA ACEPHALA.

Destitute of a distinct head, or neck.

The animals of this group are much more simple in their organization than those of the preceding division. In none of the species are there any rudiments of organs of hearing or of sight. They are destitute of jaws or other hard parts about the mouth. They all inhabit the water, and possess branchiæ. The organs of the two sexes are incorporated in the same individual, and reciprocal union is unnecessary. They are either oviparous, or ovoviviparous. The presence or absence of a shelly covering, furnish characters for a twofold distribution of the groups.

SECT. 1.—*Acephala Conchifera.*

The shell in all cases is external and bivalve; and exhibits very remarkable differences in the form, relative size, and connection of the valves. The cloak is likewise in the form of two leaves, corresponding with the valves which protect it.

ORDER I.—BRACHIOPODA.

Mouth with a spiral arm on each side fringed with filaments.

The genera included in this group constitute the *Brachiopoda* of Cuvier. The lobes of the cloak are free anteriorly. From the body, between the lobes, the arms have their origin at the margin of the mouth. These arms are capable of folding up spirally. All the species are permanently attached to foreign bodies, and inhabit the sea. Their nervous and reproductive systems have received but little elucidation.

1st Subdivision.

Shell supported on a fleshy peduncle.

GENUS *LINGULA*. Valves equal, the apex of both attached to the peduncle.

The peduncle is nearly cylindrical, cartilaginous, and covered with a membrane consisting of circular fibres. The valves are oval, flat, and destitute of teeth, or elastic ligaments. The adductor muscles are numerous, obliquely placed, and appear capable of giving to the valves a considerable degree of lateral motion. The cloak is thin, and has interspersed muscular fibres. Its margin is thickened, and fringed with fine hairs of nearly equal length. The

arms are fleshy in their substance, conical, elongated and compressed in their form, and ornamented on the external surface with thick set fringes or tentacula. The mouth is simple, and situate between the arms at their base. There is no enlargement of the alimentary canal, which can be regarded as a stomach, and the anus is a simple aperture situate on the side. There are marked indications of salivary glands and a liver. The blood is conveyed to the gills by two vessels, which are divided at the separation of the lobes into two branches, one of these going to the half of one lobe, and another to the opposite half of the other lobe. Two systemic veins occupy a similar position, and return the aerated blood to the two lateral systemic ventricles. The gills themselves are arranged in a pectinated form, on the inner surface of each lobe of the cloak. There is nothing known of the nervous or reproductive systems of this animal.

The *Lingula unguis* is the only species of the genus, and appears to be confined to the Indian seas. The valves were first figured by Seba, together with the peduncle by which they are supported. Linnæus having seen only one valve, conjectured that it belonged to *Patella*, and named it *P. unguis*. Chemnitz examined both valves, without the peduncle, and pronounced them connected with the genus *Pinna*. Bugiere, aware of Seba's figure, contemplated the formation of the new genus for its reception, which Lamarck executed. M. Cuvier afterwards dissected one of the individuals, which Seba had possessed, and unfolded characters in its organization, sufficient not only to warrant the construction of a new genus, but a new class.

Some petrifications have recently been referred to this genus; but, in the absence of all vestige of the peduncle, we do not consider the mere form of the shell as furnishing characters sufficiently obvious and precise to warrant such distribution.

TEREBRATULA. Valves unequal, the peduncle passing through an aperture in the largest valve.

The following interesting information, from the dissections of Mr. Owen, will be read with pleasure by the student of the anatomy and physiology of the mollusca.

The mantle adheres very closely to the valves: the lobe which corresponds to the perforated valve is traversed longitudinally by four large vessels; the opposite lobe is similarly traversed by two such vessels. Its margins are thickened, not as in the *Lamellibranchiate Bivalves* from contraction, but owing to a peculiar structure connected with respiration. They are puckered at regular distances, the puckerings being apparently caused by the insertion of delicate *cilia*, which pass as far within the mantle as they project out of it, but which are so minute as to be observable only by means of a lens. In the interspaces of the *cilia* the margin of the mantle is minutely fringed, and within the fringe is a canal, which extends along the whole circumference. From this canal the large vessels of the mantle lobes take their origin: they may be regarded as the branchial veins conveying the aerated blood to the two hearts, which are situated exterior to the liver, and just within the origin of the internal calcareous loop: they are accompanied in their course by much smaller vessels, probably the branchial arteries. Such is apparently the system of respiration in *Terebratula*.

The *viscera* occupy a very small space near the hinge. The alimentary canal commences by a small puckered mouth, situated immediately between the folded extremities of the arms. It passes backwards, and expands into a membranous stomach, surrounded by the liver, a bulky gland of a green colour and minute follicular texture, which communicates with it by many orifices. The intestine passes down to the hinge, and then turns to the right side and terminates between the two mantle-lobes. No trace of a salivary gland was found.

The generation of *Terebratula* is that of the ordinary Bivalves. In two of the larger specimens the ova had insinuated themselves between the layers of the mantle, and partly surrounded the branchial vessels. When so far advanced they obscure the organization of the mantle which adapts it for respiration: this organization is consequently most satisfactorily observed in very young individuals.

The peculiar internal testaceous apparatus or loop connected with the hinge and supporting the arms, possesses some elasticity, and when acted on by the muscles, becomes in its reflected part sufficiently convex to press upon the perforated valve and separate it slightly from the opposite one; thus compensating for the absence of the thick arms of *Lingula*, which, in their protrusion, push open the valves, and also for that of the elastic fibres, constituting the ligament of ordinary Bivalves.

In the *Orbicula lamellosa* the same intelligent observer traced along the whole circumference of the valves, shining cilia projecting for an extent varying from two to four lines: they are consequently much longer than in *Terebratula* and in *Lingula anatina*, and are rather longer than in *Lingula Audebardi*, Brod. On examination under a higher power they are observed to be beset with smaller setae, which probably give them greater power in determining the respiratory currents. The mantle is similarly vascular to that of *Terebratula*, there being, in the upper lobe, four principal trunks (comparatively, however, much shorter than in that genus); and two in the lower. These trunks terminate in sinuses, situated close, and two strong tendinous membranes, which circumscribe the visceral mass, and to which the mantle-lobes firmly adhere. Here the veins of both mantle-lobes join, and the common trunk or sinus passes obliquely through the membrane, and may be plainly seen distributing ramuli over the liver and ovary.

The muscles and viscera form a rounded mass, situated in the posterior half of the shell. The mouth is seated between the base of the arms. The oesophagus passes obliquely through the tendinous wall of the viscera in a direction towards the upper valve: it becomes slightly dilated, and is then surrounded by the liver. The intestine is continued straight to the opposite end of the visceral cavity, is there again contracted, makes a sudden bend upon itself, and returns to the middle of the right side of the visceral belt, which it perforates obliquely, and terminates between the lobes of the mantle a little below the bend of the arms. The liver is of a beautiful green colour, and consists of a congeries of elongated follicles, closely compacted together, which communicate by numerous orifices with the stomach. As in *Terebratula*, there is no salivary gland.

In *Lingula Audebardi*, Brod., there is also no salivary gland; and Mr. Owen is therefore disposed to believe, that the gland described as such in *Lingula anatina* by Cuvier, was only a portion of the liver, from which the colour had probably been removed by long maceration in spirit.

In the want of salivary glands the Brachiopoda would seem to agree with the ordinary Bivalves. Destitute, like them, of any hard parts about the mouth for comminuting alimentary substances, glands for pouring in a fluid to blend with the food during that operation, are not wanted.

The nervous system in *Terebratula* was not detected by Mr. Owen. In *Orbicula* two small ganglia were found on the side of the oesophagus next the perforated valve; from which two filaments, accompanying the oesophagus through the membranous wall, immediately diverge and pass exterior to the anterior shell muscles, proceeding with corresponding arteries to near the heart, beyond which he could not trace them. A single small ganglion is situated on the opposite side of the oesophagus, but on a plane posterior to the preceding; this is probably the cerebral ganglion for giving off nerves to the free spiral extremities of the arms, close to the base of which it is situated.

ORDER II.—BIVALVIA.

Mouth destitute of fringed spiral arms.

The animals of this group form the class Conchifera of Lamarck, the Bivalvia of the older naturalists.

The shells exhibit great variety of form and relative size. They are joined together at the hinge, which is either plain or toothed, and corresponds in position with the back of the animal. The connection of the two valves is secured by the intervention of an elastic horny ligament, the office of which is to keep the valves open. It is either external or internal. The valves are closed by means of *adductor muscles*, intermixed with tendons, and, passing transversely through the animal, adhere to the corresponding places in the inside of each shell. By the contractions of these muscles the free edges of the valves are brought into contact, at the same time that the ligament is compressed or stretched, according as it is internal or external. The number of muscular impressions is employed by Lamarck in the division of the Bivalvia into two orders, *Dimyaires* and *Monomyaires*. This distinction, however, he has not attended to with care, as in his family *Mytilacées*, which he includes in his second order, or those having one adductor muscle, there are obviously two adductor muscles, although the one is certainly much larger and more complicated than the other. Besides these impressions of the adductor muscles, there are others connected with the foot and byssus. The cloak lines the inside of the shells. In some cases it is entirely open, when the border corresponding with the free margin of the shell is thickened, and more or less fringed with contractile irritable filaments. In other cases the cloak in front is more or less united, and even forms tubular elongations, which are termed *syphons*.

Locomotion is denied to many species of this order. Among these some are immoveably cemented to rocks and stones, as oysters; a few are attached by a cartilaginous ligament, as the *Anomia*; while others are fixed by means of a *byssus*. This last organ consists of numerous filaments issuing from a complicated apparatus in the breast, connected with a secreting gland and with the shell by the intervention of tendinous bands. The *foot* is seated a little towards the mouth, is usually tongue-shaped, capable of considerable elongation, with a furrow on its posterior surface. This organ, where a byssus is present, is considered as employed in spinning and fixing the threads. When there is no byssus, it either acts as a sucker, enabling the animal to crawl among the surface of bodies, or as a paw, to dig holes in the sand or mud. None of the species can float in the water. They either crawl or leap, the last kind of motion being effected by suddenly opening and shutting the valves. In securing a residence, some of the species bore into different substances by means of a rotatory motion of the shell. It was at one time supposed that the dwelling was formed by a secretion affecting the solution of the surrounding substance. But the very different substances penetrated by the same species, as limestone, slate-clay, and wood, forbid us to entertain such a supposition.

The nervous system is here but little developed. The superior and inferior ganglia, surrounding the gullet, give rise to all the nervous filaments which proceed through the body.

The digestive organs are scarcely less simple. The food is soft and swallowed entire, and either brought to the mouth by accident, or by eddies produced in the water by the opening and shutting of the shells, aided in some cases by the syphons.

It may be proper here to state, in order to understand the relative situation of the parts, that, upon laying the animal upon its back, and opening the cloak, the abdomen appears to occupy the middle longitudinally, and the branchia to be arranged on each side. The mouth is situated

Mollusca. at the anterior extremity, and consists of a simple aperture entering into the gullet, or rather stomach. It is surrounded by four flattened moveable tentacula, two of which in some are in part united with the cloak, while in others they are free to the base. In their structure they resemble the branchiæ. The stomach is full of cells, the bottom of each pierced with a biliary duct. A singular organ, termed the *crystalline process*, cylindrical, cartilaginous, and transparent, is found in some species projecting into the cavity of the stomach. The liver is large, surrounds the stomach, and pours out its contents by numerous openings. The intestine terminates posteriorly by a tubular anus.

The branchiæ consist of two ribbands on each side, extending the length of the body, free on the sides and margin, and striated transversely. These plates are frequently of unequal size. The blood is brought to these by means of pulmonic veins, without the intervention of the heart. The aerated blood is transmitted to a systemic heart, consisting of one or two auricles, and a ventricle.

The reproductive organs of the Bivalvia, hitherto examined, consist of an ovarium occupying the sides of the body, and penetrating the membranes of the cloak. They appear to have the organs of both sexes incorporated, and to propagate without intercourse. Lamarck is disposed to consider impregnation produced by the male fluid dispersed through the water; a supposition unsupported even by analogy in the animal kingdom. Many species are ovoviviparous; in which case the eggs when ripe pass into the gills, where they are hatched.

The methodical distribution of the Bivalvia appears to be attended with peculiar difficulties, in consequence of the uniformity which prevails in the structure and disposition of their organs. The characters furnished by the shell, though useful in the construction of generic as well as specific distinctions, have been abandoned by those who prefer a knowledge of the structure, rather than the form of an animal. The characters derived from the presence of a byssus, a foot, or syphons, appear to be nearly of co-ordinate importance. M. Cuvier gives the preference to those founded upon the appearances of the syphon, by the aid of which the genera may be distributed into five families, an arrangement which, though liable to some objections, may be adopted with advantage. These groups, however, may be considered as occupying a much higher rank, and each as including numerous families.

1st Subdivision.

Cloak open.

There are no syphons, the anterior margin of the cloak being as open as the mouth of the shell. When the valves open, the water comes immediately in contact with the branchiæ and mouth. The margin of the mantle has a double fringe of filaments.

1st Tribe.

Valves closed by one adductor muscle.

A. *Pectenidæ*. Animals free or fixed only by a byssus. Furnished with a foot.

Into this family, contemplated by Lamarck, the following ill assorted genera may be placed: *Pecten*, *Lima*, *Pedum*, *Plagiostoma*, *Vulsella*, *Placuna*, *Gryphæa*, *Perna*, *Gervillea*, *Inoceramus*, *Malleus*, and *Crenatula*.

B. *Ostreidæ*. Shell cemented to foreign bodies. Body destitute of a foot.

To this family the following genera are related: *Ostrea*, *Anomia*, *Spondylus*, and *Plicatula*.

2d Tribe.

Shell closed by two adductor muscles.

The two genera, *Avicula* and *Meleagrina* (of Lamarck), form one family of this tribe; the genus *Pinna* another; and the *Arcadæ* a third, including *Arca*, *Pectunculus*, *Nucula*, *Cucullæa*, *Trigonia*, and *Castalia*.

2d Subdivision.

Cloak more or less closed, forming syphons.

The further division of this group depends on the modifications of the syphons, or aperture of the cloak.

1st Tribe.

The union of the cloak forming only one syphon. This is situate posteriorly opposite the anus, and serves for the ejection of the excrements. The other large opening allows the water to enter to the mouth and gills.

This tribe may be divided into two families. The first, *Mytilidæ*, will include the genera *Mytilus*, *Modiolus*, and *Lithodomus*, which are furnished with a byssus. The second, *Unioridæ*, will embrace *Unio*, *Hyria*, *Anodonta*, and *Iridina*. They want a byssus.

M. Cuvier is disposed to place in this group the genera *Cardita*, *Venericardia*, and *Crassatella*.

2d Tribe.

Cloak closed posteriorly, and anteriorly forming three apertures. The first serves for the passage of the byssus, and is the largest. The second admits water to the branchiæ and mouth; and the third is opposite the anus. The valves are closed by one adductor muscle. There are only two genera belonging to this tribe, *Tridacna* and *Hippopus*.

In the two remaining tribes there are three openings in the cloak. Two of these are posterior, and near each other; sometimes, indeed, they are tubular and united. There is no byssus, but always a foot.

3d Tribe.

Anterior opening large, allowing the water free access to the mouth and gills, and the feet freedom of motion. The structure of the animals is yet too imperfectly examined to enable any one to establish families on permanent characters. The attempt which Lamarck has made may be considered as a complete failure, independent of the wanton changes of nomenclature with which it is chargeable, whilst the efforts of Cuvier have not been attended with greater success. The following are the principal genera belonging to this tribe: *Chama*, *Isocardia*, *Cardium*, *Donax*, *Cyclas*, *Corbis*, *Tellina*, *Loripes*, *Lucina*, *Venus*, *Capsa*, *Petricola*, *Corbula*, and *Mactra*.

4th Tribe.

Anterior opening small, and not exposing the mouth or gills.

In this tribe the mantle is closed in front; and even when the valves are open, neither mouth nor gills are visible. The anterior opening serves for a passage to the foot, and the posterior openings, in the form of two long tubes, united by a common membrane, serve for the entrance and exit of the water to the mouth and branchiæ, and the ejection of the fæces, the dorsal syphon serving the latter purpose. The cuticle of the shell covers also the exposed portion of the cloak, so that, when the animal is removed from the shell, it remains as a loose membrane on the margin of the valves, as was first observed by Reaumur. All the genera prefer concealment, burrowing in sand, mud, or wood, with the head downwards, and the syphons rising to the surface. The following genera belong to this tribe: *Mya*, *Lutraria*, *Anatina*, *Glycemeris*, *Panopea*, *Pandora*, *Gastrochena*, *Bysomia*, *Hiattella*, *Solen*, *Sanguinolaria*, *Pholas*, *Teredo*, *Xylophaga*, *Clavagella*, and *Fistulana*.

SECT. II.—*Acepala Tunicata*.

Covering soft or coriaceous.

The formation of this interesting group of animals was first publicly announced by Lamarck in his *Histoire Naturelle des Animaux sans Vertèbres*, tom. iii. p. 80, (1816.) The labours of Desmarest, Lesueur, and Cuvier, aided by the descriptions of Ellis and Pallis, paved the way for the masterly efforts of Savigny, to whom we owe the most extensive, new, and accurate information yet given concerning the animals of this group. His observations are contained in his *Recherches Anatomiques sur les Ascidies composées*,

Mollusca, *et sur les Ascidies simples*, inserted in his *Mémoires sur les Animaux sans Vertèbres*. 8vo, Paris, 1816.

The covering of the animals of this group consists of an external and internal sac or tunic, which are either entirely united or unconnected, except at the apertures. The surface is smooth in some, and rough in others, and in a few species defended by an artificial covering of agglutinated shells and sand. The sacs are furnished with muscular bands, and are capable of contraction. Some of the species, by means of contractile movements, float about in the water; others, receiving that element into the branchial cavity, and ejecting it forcibly at the opposite one, push themselves forward. Many, however, are fixed during life to seaweeds and stones.

The apertures of the tunic are two in number, unless in the doubtful genus *Mammaria*. The one, frequently the largest, is destined for receiving the water into the cavity to supply the mouth and gills. This is termed the *branchial* cavity. The other is destined for the exit of the water, the eggs, and the fæces, and termed the *anal* opening. These apertures are sometimes placed near each other, at other times at opposite extremities of the body, and variously provided with tentacula or valves.

The mouth is simple, destitute of spiral arms, and opening in the anterior of the cavity of the body between the branchiæ, as in the other *Acephala*. It possesses neither jaws nor tentacula. The alimentary canal is very simple, and can scarcely be distinguished into gullet, stomach, and intestine. The food is soft, and such as the bounty of the waves bestows. The liver adheres to the stomach, and in many species is divided into distinct lobes.

The circulating system appears to be reduced to a single systemic ventricle. The gills cover the walls of the cavity, in the form of ridges, more or less complicated, and seldom symmetrical.

The reproductive organs consist of an ovarium, either simple or complicated, with some additional glands, the uses of which have not been ascertained. The species are considered as hermaphrodite, and independent of reciprocal impregnation. They appear not only to be oviparous, but to be gemmiparous and compound, many individuals being organically connected, and capable of simultaneous movements. They are all inhabitants of the sea.

1st Subdivision.—*Dichitonida*.

Interior tunic detached from the external one, and united only at the two orifices.

The branchiæ are large, equal, and spread on the central walls of the inner sac. The branchial orifice has an inner membranaceous denticulated ring, or a circle of tentacula.

1st Tribe.

Body permanently fixed to other bodies.

In this tribe the branchial and anal orifices are not opposite each other, and do not communicate through the branchial cavity. This cavity at its opening is furnished with tentacular filaments. The branchiæ are conjoined anteriorly.

A. Simple.

This division includes the genus *Ascidia* of Linnæus. The individuals are independent of each other, and although they frequently adhere together in clusters, they are destitute of a common covering, or organical connexion.

1. *Apertures furnished with four rays*.

The animals of this group have the external tunic coriaceous, dry, opaque, rough, folded, and frequently covered with extraneous bodies, or inclosing such. The branchial orifice has four rays, the anal one the same, or divided transversely. The branchiæ are divided longitudinally into persistent regular deep folds.

a. Body pedunculated.

The peduncle, in this division, may be said to have its rise in the summit of the body, which it serves to suspend.

The abdomen is lateral. The meshes of the branchiæ are destitute of papillæ.

GENUS *BOLTENIA*.—The tentacular filaments of the branchial circle are compound. There is no liver, and the ovarium is compound. Only one species is known, *B. fusiforme*. Savigny, *Mem.* tab. i. f. 1., and tab. v. f. 5. It is the *Vorticella Bolteni* of Lin. and the *Ascidia Clavata* of Shaw.

b. Body sessile.

M. Savigny describes this group as a genus, which he terms *Cynthia*, which he divides into four sub-genera.

(A.) Tentacular filaments of the branchial orifice compound. The folds of the branchiæ more than eight in number. The liver distinct, and surrounding the stomach. Ovarium divided, with one division at least on each side the body. The intestine destitute of a rib.

GENUS *CYNTHIA*.—Meshes of the branchiæ unchanged by the folds. *C. Momus*. Sav. tab. i. f. 2.

GENUS *CÆSIRA*.—Meshes of the branchiæ interrupted by the folds. *C. Diona* of Sav. tab. vii. f. 1. The *Ascidia quadridentata* of Forskæl.

(B.) Tentacular filaments of the branchial orifice simple. The folds of the branchiæ eight in number, four on each side, and the meshes uninterrupted. Intestine strengthened by a cylindrical rib from the pylorus to the anus. Liver absent or indistinct.

GENUS *STYELA*.—Ovarium divided, one division at least on each side. *S. Canopus*. Sav. tab. viii. f. 1.

GENUS *PANDOCIA*.—Ovarium single, and situate in the fold of the intestine. The *Ascidia conchilega*, a native species is the type.

2. *Apertures with indistinct rays, or more than four*.

The external tunic is here soft, easily cut, and translucent. The rays (when existing) of the branchial orifice amount to eight or nine; and those of the anal to six at least. The branchiæ are destitute of longitudinal folds. The tentacular filaments of the branchial circle are simple. Liver indistinct. Ovarium single.

a. Body pedunculated.

The stalk is here placed at the base, and serves to support the body, being of an opposite character from that of the *Boltenia*.

GENUS *CLAVELINA*.—Branchial and anal orifices without rays. Angles of the branchial meshes simple. Intestine destitute of a rib. The *Ascidia clavata* of Pallas, and the *A. lepadiformis* of Müller belong to this genus; the latter of these is now recorded as a British species.

As connected with this group the small *Ascidia*, figured and described by Mr. Lister in the *Philosophical Transactions* for 1834, deserves particular notice, as the following important observations which he has recorded, sufficiently indicate. They will indeed be perused with peculiar interest by all who are practically engaged in the study of molluscous animals.

This compound animal occurs in groups that consist of several individuals; each having its own heart, respiration, and system of nutrition, but fixed on a peduncle that branches from a common creeping stem, and all being connected by a circulation that extends throughout. Their parts of such transparency that their interior is easily seen. Their external shape is that of a pouch, compressed at the sides, and fixed at the hind part of its base upon the peduncle.

Its two openings are in the form of very short tubes; that of the mouth at the top of the pouch, and that of the funnel in front. The longest diameter, from the peduncle to the space between the openings, is about .085 inch.

The outer covering is a tough coat, a continuation of the peduncle, more pliable near the openings; lined interiorly with a soft substance or mantle, in which a ramifying circulation is very distinct. A great part of the interior is occupied by the branchial sac, which is subcylindrical, flattened

Mollusca. at the sides, and has its axis vertical; its cavity terminating upwards in the oval opening, and being closed at the bottom. It is united to the envelope, or to the mantle above and behind; the juncture, beginning in front of the oval opening, extends backwards on each side of it, and then downwards in two lines; between these, along the middle of the back, is a vertical compound stripe, that seemed to me cartilaginous. At the bottom the sac appears to be enveloped by the soft substance of the mantle, but at its sides and front a vacant space is left between them, that ends in the opening of the funnel. The branchial sac is more compressed towards its lower part; and here are placed, externally to it, the heart on the left, and the stomach and other viscera on the right side, the vent opening upwards at the front into the funnel. On its sides and front the sac is perforated by four rows of narrow, vertical, irregularly oval holes or spiracles, about sixteen in each row, placed at less than the diameter of one apart from each other. Through these the water, which flows constantly in at the mouth when its orifice is open, appears to be conveyed to the vacant space between the sac and mantle, and it then escapes at the funnel. The sac seems extremely thin between the spiracles; but their edges are thickened, as if cartilaginous; and they are lined with closely set ciliae, which, by their motion, cause the current of water. When these are in full activity, the effect upon the eye is that of delicately-toothed oval wheels revolving continually, in a direction ascending on the right and descending on the left of each oval, as viewed from without; but the ciliae themselves are very much closer than the apparent teeth, and the illusion seems to be caused by a fanning motion given to them in regular and quick succession, which will produce the appearance of waves, and each wave here answers to a tooth. The spaces between the rows of spiracles are of much more substance than the intervals of the spiracles; some ligaments are stretched from them across the side cavities to the mantle, which seem intended to keep the branchial sac expanded. These spaces also support finger-like processes, about eight in a row, that project nearly at right angles into the central cavity.

The central cavity I shall venture to call the mouth, though the mouth is said by Cuvier to lie at its bottom. The large short tube at its opening ends in five or six obscure indentations; it can be drawn in and closed at the will of the animal, as can the opening of the funnel. At the bottom of the tube the entrance of the mouth is guarded by simple tentacula, some longer, some shorter, ranged subalternately: their number was not ascertained. Whatever little substances, alive or inanimate, the current of water brings, flows in unless stopped by the tentacula, and they do not appear fastidious, to the mouth, and lodge somewhere on the sides of it. A lively animalcule will sometimes disengage himself by struggling, and dart about in the cavity till he lodges on some other part; or, if a morsel is found unsuitable, it is ejected by the funnel's being closed, and the branchial sac suddenly contracted vertically. Mostly, however, whatever part the food lodges on, it travels from thence horizontally with a steady slow course towards the front of the cavity, where it reaches a downward stream of similar materials, and they proceed together, receiving accessions from both sides, and enter at last at the bottom, the *œsophagus*: this is a small flattened tube which carries them, flowing on in the same way, without any effort of swallowing, towards the stomach. The tube takes a sharp curve upwards and backwards before arriving there.

It is extraordinary that these particles pass along in the mouth just behind the spiracles, when the ciliae are in full activity, without being at all affected by them. I have, in some positions, seemed to catch a glimpse of a membrane suspended within, too transparent to be commonly seen. One may imagine the water to pass to the spiracles, strain-

Mollusca. ed through the meshes of such a membrane, and the food to be carried along it by invisible villi; but this is mere conjecture. The projecting fingers have the effect, whether intended for such a purpose or not, of detaining some prisoners more bulky than the usual food of the animal, for, in several individuals, I met with small shrimp-like crustacea confined between the rows: one escaped during an observation, another, after three days, seemed as lively as when first swallowed.

The stomach runs backward horizontally; its fore-part had an inflated look when seen from the side, and, when from below, that of possessing two lateral lobes. The food after accumulating here was observed to be pressed onward to the hinder portion, leaving a narrow opaque line of connexion with the *œsophagus*; the rest of the fore-part, of which the apparent volume was nearly as before, having an ochreous tint; this was inferred to be the liver, enveloping the stomach above and on the sides, and accords with its place in other *ascidiae* and *mollusca*. The line is continued by the intestinal canal that rises and then bends forward, taking the form of a reversed S, and terminates in an ascending rectum and sphincter. The *fæces* are considerable, as might be expected, where the food is taken with so little discrimination. Transparent vessels, that may be supposed lactaels, ramify along a part of the intestine and meet at a collection of globular bodies, from whence two flattish lobes extend backward; in others these are wanting. From the meeting of the vessels two branches ran, one downwards and backwards, which was lost under the stomach, the other forwards; and from the direction it took, I suppose it might communicate with a main stream of blood near the heart. Some individuals had not the projection above the vent observable in others.

But the part that struck me as most remarkable in this creature was the circulation, of which a good view can be obtained through the transparent coat, for the particles of the blood are numerous, and, though not uniform in size or shape, are mostly between .00025 and .0002 inch in diameter, and approaching to globular. They are easily measured, as in the intervals between the spiracles, they pass mostly but one at a time.

The creeping tube, which unites the individuals of a group, is the channel for two separate currents of blood, an upward and a downward one, that are flowing at one and the same time, and that send off each branch to every peduncle: the blood thus passes into the animal by one current, while another carries it back. One of these canals communicates at the termination of the peduncle with the heart, which is placed, as has been mentioned, near the bottom of the branchial sac on the left side, and consists of a transparent ventricle, or boyau, running forward and a little slopping downward, in a channel hollowed to contain it. Along the whole length of the boyau a part on one side of its axis seems fixed to the channel, the rest free and contractile.

When the blood entered the heart from the peduncle, contraction began at the middle of the ventricle, impelling onward the contents of the fore part; and the contraction of the back part followed in the same direction, so as for the whole to have the effect of one pulsation; the heart was then filled again by a flow from the peduncle. The intervals of the pulse were pretty regular in the same individual, but in different ones they varied from two seconds to one and a half second. Part of the blood thus impelled formed a main upward stream along the front of the branchial organ, branching off at each of the horizontal passages between the rows of spiracles, and at one above them on a line with the junction to the mantle on each side. All these again united and formed a downward current behind. The horizontal channels were connected also by the smaller vertical passages between the spiracles; the set of the current in

Mollusca. the latter being upwards for the two lower rows, and downwards for the two upper ones.

Another larger portion of the blood, on leaving the heart, immediately divided into many ramifications that spread like a network over the stomach and intestines and the soft substance of the mantle. Of these a part run into the horizontal passages above the branchial sac, a part into the descending back stream; a large portion, after leaving the intestines, took a short course, and, collecting into one channel, flowed into that stream near the bottom, and, all united, then entered the peduncle and constituted the returning current that went to circulate in other animals of the group.

After this circulation had gone on for a while the pulsations became fainter for a few beats, and the flow slower, and suddenly, with but a slight pause, the whole current in all its windings was reversed. The heart gave the opposite impulse; the channel in the peduncle, that before poured in the blood, now carried it back, and the other the contrary, and every artery became a vein. These changes continued and succeed each other alternately, the average time of the currents being the same in both directions, but the period of each varying within a single observation as much as from thirty seconds to two minutes. The phenomenon, like the currents in the *Sertulariae*, was invariably met with in every animal of the species that came under my notice.

Sometimes, when the creeping tube or the peduncle has been injured, the circulation of an individual is in consequence insulated, but without appearing to impair any of its functions. I severed one at the part where it joined the peduncle, when for a few seconds the pulsation ceased; it then began irregularly and with considerable pauses, and increased in steadiness as it went on. At first the impulse given by the heart was towards the front, and the downward back stream, instead of flowing out at the wound, was poured into the hinder end of the ventricle; but when the current was reversed part of the blood was driven for a time through the stump of the peduncle into the water: however, it soon stanchied, and all the vital actions went on as before the separation, except that at the beginning of every pulsation there was a slight recoil.

In one case where the circulation did not extend to another animal, one channel, and only one, was open in the peduncle, and in this a small current ran to and fro according to the direction of the impulse given by the heart. Some animals, which had probably been injured, but were still connected with other vigorous ones, seemed to be in course of absorption. One was observed in which the soft parts were so shrunk as to occupy a small part only of the tunic; the currents of its peduncle extended into this mass, but the heart, or motion of branchiae, was visible. Upon looking at the same the next day, the tunic was empty, the soft matter and circulation reaching only to the end of the peduncle. I also once noticed a flux and reflux of the blood in a creeping stem, where the current did not communicate with any animal.

In some of the last mentioned particulars this *Ascidia* bears a resemblance to the *Sertulariae*, and, like them, it increases by sprouts: the two streams of the stem run through the bud before its organs are developed. No proper motion was seen in the particles of its blood, like that of the *Sertulariae*.

In a sessile *Ascidia*, nearly half an inch in length, of which the coat was too rough and opaque to allow an inspection of the branchiae, the circulation was distinctly visible in the mantle near the openings, and the particles in the blood were only of about the same size as above.

b. Body sessile.

The branchial orifice with eight or nine rays, and the anal with six. The angles of the branchial meshes with

papillæ. No liver. A cylindrical rib extending from the pylorus to the anus.

(A.) Tunic and branchial cavity straight.

GENUS *PIRENA*.—The branchial sac as extended as the tunic. Stomach not resting on the intestine. *P. phusca* of Forskael is the type, to which Savigny has added three other species. The *Ascidia prunum* of Müller, a native species, may be referred to this genus.

GENUS *CIONA*.—Branchial sac shorter than the tunic, and exceeded by the viscera. *Ascidia intestinalis*, Lin. is a native example of this genus.

(B.) Tunic turned up at the base.

GENUS *PHALLUSIA*.—Branchial sac extending beyond the viscera into the pouch of the sac. Stomach resting on the mass of viscera. The *Ascidia mentula* of Müller, a native species, is the type.

There are two genera supposed to be nearly related to the preceding, which are involved in great obscurity. The genus *Bipapilaria* of Lamark appears to be pedunculated, with two apertures, each furnished with three setaceous tentacula. The *Mammaria* of Müller has only one terminal aperture. One species inhabits the British seas.

B. Compound.

The animals included under this division were formerly inserted in the genus *Alcyonium* of Linnæus, and placed among the Zoophytes. They are compound animals, many individuals united by a compound integument, and arranged according to a uniform plan.

In some cases, there is only one system of individuals in the mass, in other cases, there are many similarly arranged and contiguous. The tentacular filaments of the branchiae appear to be distinct. They are destitute of the intestinal rib which occurs in some of the preceding genera.

1. Branchial Orifice Radiated.

a. Branchial and anal orifices, with six rays.

(A.) Body sessile. The angles of the branchial meshes furnished with papillæ. The thorax, or cavity containing the branchiae, cylindrical. The abdomen is inferior, with a stalk. Ovary sessile, and single.

GENUS *DIAZONA*.—Body orbicular, with a single system of animals disposed in concentric circles.

The substance is gelatinous. The ovary enclosed in fold of the intestine. *D. violacea* of Sav. tab. ii. f. 3.

GENUS *POLYZONA*.—Body polymorphous, with many systems disposed subcircularly.

The body is subcartilaginous. The individuals are disposed irregularly around the common centre. Savigny inadvertently termed this genus *Distoma*, a name long preoccupied amongst the intestinal worms. The *Alcyonium rubrum* of Plancus, and the *Distomus variolosus* of Gaertner, belong to this genus. The last is a native species.

(B.) Body pedunculated.

GENUS *SIGILLINA*.—Body a solid cone, consisting of a single system of many individuals, irregularly disposed, one above the other.

The thorax is short, and hemispherical. The angles of the branchial meshes destitute of papillæ. The abdomen is inferior, sessile, and larger than the thorax. The single ovary is pedunculated. *S. australis*, Sav. tab. iii. f. 2., brought from New Holland, by M. Peron, is the only known species.

b. Branchial orifice only furnished with six rays.

(A.) Body pedunculated. System single, circular, and terminal.

GENUS *SYNOICUM*.—Anal orifice rayed.

The body is cylindrical. The anal orifice has six very unequal rays; the three largest forming the exterior margin of the central star. The stomach is simple. The angles of the branchial meshes destitute of the papillæ. Ovary single, sessile attached to the bottom of the abdomen, and

Mollusca. descending perpendicularly. The *S. turgens* of Phipps is the type.

GENUS SYDNEUM.—Anal orifice simple and tubular.

The body is inversely conical. The stomach surrounded with glands. Intestine spirally folded. Ovarium pedunculated. The *S. turbinatum* is the only known species, and was sent to Savigny by Leach from the British seas.

(B.) Body sessile, polymorphous.

(a.) Each system with a central cavity.

GENUS POLYCLINUM.—Systems numerous, convex stellular. Individuals arranged irregularly round the common centre. Abdomen inferior pedunculated, and less than the thorax. Ovarium single, pedunculated, and attached to the side of the abdominal cavity, and drooping.

M. Savigny describes one species from the Mauritius, and five from the Gulf of Suez.

(b.) Systems destitute of the central cavity, and the angles of the branchial meshes without papillæ.

GENUS ALPIDIUM.—Individuals in a single row round the common centre.

The thorax is cylindrical. The abdomen inferior, sessile, and of the size of the thorax. Ovarium single, sessile, placed at the bottom of the abdomen, and prolonged perpendicularly. Savigny divides the genus into two tribes. In the first, the individuals are simply oblong, with an ovary shorter than the body, as *A. ficus* (*Alcyonium ficus*, Linn.) In the second, the individuals are filiform, with an ovary longer than the body, as *A. effusum* of Savigny, tab. xvi. f. 3.

GENUS DIDEMNUM.—Individuals in distinct systems.

The thorax is short and subglobular. The abdomen inferior, pedunculated, and larger than the thorax. The anal opening is obscure. The ovary is single, sessile, and placed on the side of the abdomen. *D. candidum* and *viscosum*, from the Gulf of Suez, are the only known species.

2. Branchial Orifice simple.

The species form a thin fleshy crust on stones and seaweeds. The individuals are stellularly arranged in distinct systems. The branchial orifice is circular and undivided. The abdomen is sublateral, and fixed at the bottom of the branchial cavity. The intestine is small, and the anus indistinct. The angles of the branchial meshes are without papillæ.

GENUS BOTRYLLUS.—Systems furnished with a central cavity. The systems are prominent, and consist of one or more regular concentric rows. The ovary is double, being attached to each side of the branchial sac.

This genus is subdivided by Savigny into *Botrylli stellati*, and *Botrylli conglomerati*. In the first, where the individuals are distributed in a single row, there are some species in which the individuals are cylindrical with approaching orifices, and the limb of the central cavity not apparent after death, and probably short, as the *B. rosaceus*, *Leachii* and *Borlassii*. In other species, the individuals are ovoid, with remote orifices, and the limb of the central cavity is always apparent and notched, as *B. Schlosseri*, *stellatus*, *gemmeus*, and *minutus*. In the botrylli conglomerati, in which the individuals are disposed in several rows, there is only one species, *B. conglomeratus*.

GENUS EUCÆLIUM.—Systems destitute of a central cavity. The individuals are distributed in a single row, and the ovary is single, sessile, and attached to the side of the abdominal cavity. The *E. hospitolum* of Sav. tab. iv. f. 4., is the only known species.

2. Tribe.

Body free, and moving about in the water.

GENUS PYROSOMA.—The body is gelatinous, in the form of a lengthened bag open at the widest end. The individuals are arranged perpendicularly to the axis of the central cavity, super-imposed on one another. The branchial orifice is external, without rays, and with an appendage over its upper margin. The anal orifice is opposite, and termi-

nates in the central cavity. Branchial sac destitute of folds, with a membranaceous ring at the entry. The branchiæ are disjoined. The abdomen is inferior to the branchiæ, and not separated by any contraction. Liver distinct, globular, and retained in a fold of the intestine. Ovarium double, opposite, and situate at the upper extremity of the branchial cavity.

M. Savigny divides the species into *Pyrosomata verticilla*, having the individuals arranged in regular prominent rings, as *P. elegans* of Lesueur; and *Pyrosomata paniculata*, having the individuals forming irregular circles unequally prominent, as *P. giganteum* and *Atlanticum*.

2. Subdivision. Monochtonida.

Inner tunic adhering throughout to the external one.

The body is gelatinous, transparent, and simple. The branchial cavity is open at both ends, communicating freely with the anus. The branchial orifice is in the form of a transverse slit, with one edge in the form of a valve, to accelerate the entrance of the water into the cavity. The inner tunic is strengthened by numerous transverse muscular bands, which, by contracting, diminish the diameter of the cavity, and eject the water from the anal orifice, thereby propelling the body through the water. The digestive organs are situate at the inner end of the cavity. The mouth and rectum are simple; the former placed between the two branchiæ, the latter directed towards the anal orifice. The heart is contiguous to the stomach, at the bottom of what may be termed the branchial sac, and is enveloped in a membranaceous pericardium. The branchiæ are double, not incorporated with the walls of the sac, but with two folds of unequal length. The largest is free in the middle, fixed at each extremity, and opposed to the dorsal groove, and traverses the cavity obliquely. The other extends from the base of the first to the extremity of the dorsal groove. The surface of the branchiæ consists of transverse vessels in a single range in some species, and a double range in others.

When young, many individuals often adhere, and form chains and circles. But the fully grown individuals are always detached and single.

This subdivision comprehends the species of the genus *Salpa*; they are exceedingly numerous, and appear to belong to many different genera. M. Cuvier has given indications of some of these, chiefly derived from the shape. A few are furnished with an elevated crest or fin, as the *Thalia* of Brown; a few have both extremities rounded or truncated, as *Salpa octofera* of Cuvier; others have one extremity produced, as *Holothuria zonaria* of Gmelin; and even both extremities produced, as *Salpa maxima* of Forskael. The *Salpa moniliformis*, so common in the Hebrides, and first recorded as a native by Dr. Macculloch, in his valuable *Description of the Western Isles*, vol. ii. p. 188, and imperfectly figured in its young state, at tab. xxix. fig. 2., appears to be closely allied to the *S. maxima* of Forskael, and but very remotely with the *S. polycratica* and *confederata* with which it is compared. This observer states, that "It cannot bear to be confined in a limited portion of water, as it died even in a ship's bucket in less than half an hour." With us, in similar circumstances, those taken in the evening were alive at noon on the following day.

CHAP. IV.—ON MOLLUSCOUS ANIMALS AS OBJECTS OF UTILITY.

Although molluscos furnish many articles of value to man, scarcely any naturalist has taken the trouble to enumerate the different purposes to which they have been applied, or to point out in what manner their usefulness might be increased. To the savage, shells furnish some of his most important instruments. They often answer all the purposes of a knife, and are extensively employed as a substitute for iron: with pieces of the more solid bivalves

Mollusca. he points his arrows, and forms his fish-hooks. Even when farther advanced in civilization, the canaliculated univalves sometimes constitute the rustic lamp, while the larger scallops are employed by the dairy-maid to skim her milk and to slice her butter. From the mother-of-pearl shell many useful and ornamental articles are fabricated; and calcined shells were formerly esteemed by physicians as absorbents; and are still regarded by the farmer as furnishing a valuable manure.

Shells thus appear to be of some importance in the arts of life; but the animals contained in these shells are of far greater value. As articles of food, shell-fish are extensively employed by the poor, and even hold a conspicuous place at the tables of the rich. In many places, they in a great measure support the children of our maritime population, and, in the Western and Northern Islands of Scotland, have, in years of scarcity, prevented the death of thousands.

Bivalves.
Oyster.

The kinds chiefly used in this country, as articles of subsistence, are bivalves, belonging to different genera. Among these the *Oyster* (*Ostrea edulis*) holds the most distinguished place. This shell-fish is very widely distributed in nature, being found in the seas of Europe, Asia, and Africa. But, since the days of the luxurious Romans, the oysters of Britain have been held in the highest estimation. They are found on various parts of our coasts, from the southern shores of England, to the sheltered bays among the Zetland Islands. They prefer a rough or rocky bottom, in from five to twenty fathoms water. They are fished up with a dredge and an open boat; sometimes, when in shallow water, with a rake or tongs. They are either conveyed directly to the market, or are placed in artificial ponds of sea water, where they increase in size, and acquire a fine green colour. In England this process of *fattening*, as it is termed, is chiefly conducted at Colchester, but the oysters are obtained from the little creeks between Southampton and Chichester. This fishery on the coast of England is supposed to give employment to ten thousand people, so that, independent of the addition which it makes to the articles of subsistence, it must be regarded as a valuable nursery for seamen. As an article of food, oysters are light and easy of digestion, and may be eaten in great numbers without inconvenience. They are used either raw or when pickled. In the last form, they are sent to different parts of the country, and even constitute an article of export. In Scotland, the principal oyster fishings are in the Firth of Forth; but we trust the period is not far distant, when the proprietors on the western coast of Scotland and the Hebrides will propagate this shell-fish more extensively on their shores and sheltered bays. Places fitted for their growth are every where to be met with; they require no superintending care; they would soon furnish an esteemed dish to their tables, and form a valuable addition to their trade.

Mussel.

The next shell-fish, in point of importance, as an article of food, is the *Mussel* (*Mytilus edulis*). This animal is equally widely distributed as the oyster, and is found upon our coast in the greatest abundance. It is gregarious, being found in extensive beds, which are always uncovered at low water. It is found likewise in the crevices of the rocks. In this fishery women and children are chiefly employed, and they detach the mussels with an iron hook from the beds or rocks to which they adhere by means of fine cartilaginous threads. In this country they are conveyed directly to the market; but in some places of France they are kept for a time in salt ponds, to fatten like the oyster, into which, however, they admit small quantities of fresh water. The flesh of the mussel is of a yellowish colour, and considered very rich, especially in autumn, when it is in season. It is eaten in this country either boiled or pickled, seldom in soup. To the generality of stomachs it is difficult to digest, and to many constitutions it is deleterious.

Mollusca. It is, however, in the spring, during the spawning season, that the greatest danger is to be apprehended. This noxious quality was long considered as occasioned by the *pea crab*, which is often found within the shell of mussels. It is now with more propriety attributed to the food of the mussel, which, at certain seasons, consists chiefly of the noxious fry of the star-fish; and likewise to a disease to which the animal is subject in spring, under the influence of which it melts away, and falls from the rocks. Besides being useful to man as an article of subsistence, the mussel supplies the fisherman with one of his most convenient and successful baits. It is keenly taken both by cod and haddock. To the cod-fish, however, the animal of the horse-mussel (*Modiola vulgaris*) is more acceptable.

The following unsuccessful attempt to plant a colony of mussels is recorded by Mr. Stevenson in his interesting work, (p. 73,) in which he gives the details of the erection of the light-house on the Bell-Rock: "When the workmen first landed upon the Bell-Rock, limpets of a very large size were common, but were soon picked up for bait. As the limpets disappeared we endeavoured to plant a colony of mussels, from beds at the mouth of the river Eden, of a larger kind than those which seem to be natural to the rock. These larger mussels were likely to have been useful to the workmen, and might have been especially so to the light-keepers, the future inhabitants of the rock, to whom that delicate fish would have afforded a fresh meal, as well as a better bait than the limpet; but the mussels were soon observed to open and die in great numbers. For some time this was ascribed to the effects of the violent surge of the sea, but the *Buccinum lapillus*, (Purpura,) having greatly increased, it was ascertained that it had proved a successful enemy to the mussel. The *buccinum*, being furnished with a proboscis capable of boring, was observed to perforate a small hole in the shell, and thus to suck out the finer parts of the body of the mussel; the valves of course opened and the remainder of the fish was washed away by the sea. The perforated hole is generally upon the thinnest part of the shell and is perfectly circular, of a *champhered* form, being wider towards the outward side, and so perfectly smooth and regular as to have all the appearance of the most beautiful work of an expert artist. It became a matter extremely desirable to preserve the mussel, and it seemed practicable to extirpate the *buccinum*. But after we had picked up and destroyed many barrels of them, their extirpation was at length given up as a hopeless task. The mussels were thus abandoned as their prey, and in the course of the third year's operations, so successful had the ravages of the *buccinum* been, that not a single mussel of a large size was to be found upon the rock; and even the small kind which bred there are now chiefly confined to the extreme points of the rock, where it would seem their enemy cannot so easily follow them."

The *Common Cockle* (*Cardium edule*) would deserve a place in preference even to the mussel, were it not exclusively confined to our sandy coasts and bays. It is found lodged in the sand, a few inches below the surface, its place being marked by a small depressed spot. Women and children easily dig up this shell-fish with a small spade. Cockles are sold by measure, and eaten either raw, or boiled, or pickled. They are deservedly esteemed a delicious and wholesome food in this country, although in France they are little regarded. They are in season during March, April, and May, after which they become milky and insipid. They are not generally used as a bait.

Two kinds of *Razor-fish* (*Solen siliqua* and *ensis*) are in many places of this country used as food. In Scotland they are indiscriminately termed *Spout-fish*. They are found upon most of our sandy shores, buried about a foot or two below the surface, and near to the low water mark. Their place is known by a small hole in the sand. As it is rather

Cockle.

Razor-fish.

Mollusca. a laborious operation to dig them out, Bosc informs us, that the fishermen of France throw a small pinch of salt into their holes, which always remain open by the action of the respiratory organs; that they speedily rise to the surface, and are thrown out by an iron instrument made for the purpose. The fishermen believe that it is the salt which they wish to avoid; but it is conjectured, with greater probability, that the presence of the salt water, which is thus formed by the solution of the salt, makes the animal suppose that its hole is again covered with the tide. This shell-fish was esteemed by the ancients as a great delicacy. When boiled or fried, it is certainly a very palatable morsel. When kept for a few days, it forms an excellent bait for haddock or cod, and may even be employed for that purpose in a fresh state.

Myæ. Several species of *Gapers* (*Myæ*) are used as food both in Britain and on the Continent, as the *Mya arenaria*, known to the fishermen about Southampton by the whimsical name *Old Maids*. These shells reside in the mud or shingle on the shore, and a few inches below the surface. In some parts of England and Ireland, they are much used, but, though common in Scotland, they are never sought after. Another species, the *Mya truncata*, is also very common on the coast. It prefers a hard gravelly bottom, in which it lodges near low water mark. The inhabitants of the northern islands call it *Smurslin*, and employ it, when boiled, as a supper dish. It is not so delicate as some of the shell-fish which we have noticed, but it is by no means unpalatable. The *Mya declivis* of Pennant is, according to that author, very plentiful in the Hebrides, and eaten by the gentry of that country. We suspect that he should have referred to the *Mya truncata*. These shells furnish very good baits to the fisherman.

Scallops. There are several bivalve shells, besides those which we have mentioned, employed on our coasts as articles of subsistence. The *Scallop* (*Pecten*) was held in high estimation by the ancients, and still is sought after in Catholic countries. The *Pecten maximus* is frequently used in England. It is found gregarious in moderately deep water, and is taken up by the dredge. It is pickled and barrelled for sale, and esteemed a great delicacy. The fishermen suppose that they are taken in the greatest quantity after a fall of snow. Another species, the *Pecten opercularis*, is employed for culinary purposes in Cornwall, where it is known by the name of *Frills* or *Queens*. In the Firth of Forth this species is frequently dredged up along with oysters, but it is thrown, by the Newhaven fishermen, to the dunghill, along with sea urchins and star-fish. To this list we might add the *Macra solida*, which is used as food by the common people about Dartmouth; and the *Venus pul-lastra*, called by the inhabitants of Devonshire, Pullet, and eaten by them, and known to the inhabitants of the Northern Islands by the name of Cullyock, and there used as a bait. According to Bruguiere, the *Anomia ephippium* is used as food at Languedoc, and is there considered as preferable to the oyster.—But it is now time that we turn our attention to the univalve shells, in order to ascertain their value in an economical point of view.

Univalves. The common *Periwinkle* (*Turbo littoreus*) is, in this country, more extensively used as food than any of the other testaceous univalves. This shell is easily gathered, as it is found on all our rocks which are left uncovered by the ebbing of the tide. Children are principally employed in this fishery, and the shells are sold by measure. They are in general used after being plainly boiled, and are consumed in great quantities by the poor inhabitants on the coast. The *Nerita littoralis* is also frequently gathered along with the periwinkle, as it frequents the same situations. It is, however, much smaller, and its flesh is not reckoned equally good.

Limpet. The *Limpet* (*Patella vulgata*) is equally abundant as the periwinkle, and frequents the same situations on the rocks. Although used by the ancients as an article of food, it is

seldom brought to market in this country. Among the villages along the coast of Scotland this shell-fish is frequently used, and its juice, obtained by boiling, mixed with oatmeal, is held in high estimation. It is considered in season about the end of May. The chief excellence of the limpet, however, is as a bait. It is very easily obtained from the rocks, from which the fisherman detach it with a knife, and it is eagerly seized by all the littoral fish which are sought after. To the haddock it is very acceptable.

Several species of *Snails* (*Helix*) are employed for culinary purposes. The largest of these, the *Helix pomatia*, was a favourite dish among the Romans, who fattened them with bran sodden with wine. They are still used in many parts of Europe during Lent, after having been fed with different kinds of herbs. This species was originally imported into Britain from Italy, and turned out in Surry, where it has readily multiplied. The *Helix hortensis* has also been employed as food. But, we believe that these two species are chiefly used medicinally, being administered in consumptive cases. The small species of the genus are the favourite food of the birds of the thrush kind, either in a wild or confined state.

The other univalves which we shall notice are of inferior importance as articles of subsistence. The *Fusus antiquus*, the largest of the British turbinated shells, is frequently dredged up with oysters, and, according to Pennant, “is eaten by the poor, but oftener used for baits for cod, and ray.” It is probably the same species which is noticed by the Rev. William Fraser, in his view of the Parish of Gigha and Cara in Argyshire, vol. viii. p. 48, of the *Statistical Account of Scotland*. He says it is a large white welk called *buckie* or dog-welk, and used as a bait for cod. The method of obtaining these shells for bait being ingenious, and making us acquainted at the same time with several new habits of the animal, we shall here insert it. “At the beginning of the fishing (says Mr. Fraser) a dog is killed and singed, and the flesh, after rotting a little, is cut into small pieces, and put into creels or baskets made of hazel-wands for the purpose. These creels are sunk by means of stones thrown into them. The flesh of the dog, in its putrid state, is said to attract the welk, which crawls up round the sides of the basket, and getting in at the top, cannot get out again, owing to the shape of it, which is something like that of the wire mouse-trap. After the first day’s fishing, the heads and entrails of the cod, with skate and dog-fish, are put into the creels, which are visited every day, the welks taken out, and fresh bait of the same kind put in, their being no more occasion for dog’s flesh.” The *Buccinum undatum*, and the *Purpura lapillus* are also employed as bait, and in years of scarcity as food.

This list of culinary shell-fish is far from complete, even in so far as it is a British list. The uses of these molluscous animals have seldom been taken notice of by conchologists since the days of Schonvelde, more attention having been directed to the formation of new systems of arrangement, and to the discovery of new species, than to the habits and uses of those already known.

Independently of the food which we thus obtain from testaceous animals, they furnish us with the *pearl*, one of the most beautiful ornaments of dress. This substance, equally prized by the savage and the citizen, is composed, like shells, of carbonate of lime, united with a small portion of animal matter. Pearls appear to be exclusively the production of the bivalve testacea. Among these, all the shells having a mother-of-pearl inside, produce them occasionally. But there are a few species, which yield them in greater plenty, and of a finer colour. The most remarkable of these is the *Avicula margaritifera*. This shell, which was placed by Linnæus among the mussels, is very widely distributed in the Indian seas; and it is from it and another species of the same genus, termed *Avicula hirundo*, found in the Eu-

Mollusca. ropean seas, that the pearls of commerce are procured. The *Pinna*, so famous for furnishing a byssus or kind of thread, with which garments can be manufactured, likewise produces pearls of considerable size. They have seldom the silvery whiteness of the pearls from the *Avicula*, being usually tinged with brown. But the shell which in Britain produces the finest pearls, is the *Alasmodon margaritifera*, which was placed by Linnæus in the genus *Mya*. It is found in all our alpine rivers. The Conway and the Irt in England, the rivers of Tyrone and Donegal in Ireland, and the Tay and the Ythan in Scotland, have long been famous for the production of pearls. These concretions are found between the membranes of the cloak of the animal, as in the *Avicula*, or adhering to the inside of the shell, as in the *Unio*. In the former case, they seem to be a morbid secretion of testaceous matter; in the latter, the matter seems to be accumulated against the internal opening of some hole with which the shell has been pierced by some of its foes. Linnæus, from the consideration of this circumstance, endeavoured, by piercing the shell, to excite the animal to secrete pearl; but his attempts, though they procured him a place among the Swedish nobility and a pecuniary reward, were finally abandoned; the process being found too tedious and uncertain to be of any public utility. The largest pearl of which we have any notice, is one which came from Panama, and was presented to Philip II. king of Spain, in 1579. It was of the size of a pigeon's egg. Sir Robert Sibbald mentions his having seen pearls from the rivers of Scotland as large as a bean.

Dyes.

Besides yielding us a variety of wholesome food, and valuable ornaments, testaceous animals supply us with a beautiful dye. The *Purpura* of the ancients, according to the opinion of Rondeletius, confirmed by the observations of Cuvier, was chiefly extracted from the shell termed *Murex brandaris*. Since the introduction of the cochineal insect, the use of this dye has been superseded, so that we are now in a great measure ignorant of the process which the ancients employed to extract it. In Britain there are several kinds of shell-fish, which furnish a dye of this sort, but these are seldom sought after. Cole, in 1685, published a method of obtaining it from the *Purpura lapillus*, to which Montagu, in the supplement to *Testacea Britannica*, has added several important directions. When the shell is broken in a vice, there is seen on the back of the animal, under the skin, a slender longitudinal whitish vein, containing a yellowish liquor. When this juice is applied to linen, by means of a small brush, and exposed to the sun, it becomes green, blue, and purple, and at last settles in a fine unchangeable crimson. Neither acids nor alkalies affect its colour, and it may be conveniently employed in marking linen, where an indelible ink is desirable. The *Scalaria clathrus* (*Turbo clathrus* of Linnæus) also furnishes a purple liquor of considerable beauty, but it is destructible by acids, and gradually vanishes by the action of light. The *Planorbis cornus* likewise yields a scarlet dye, but of still less permanency than the *scalaria*, as all attempts to fix it have hitherto proved ineffectual.

We cannot conclude this chapter without remarking, that the study of molluscous animals rises in importance as we perceive its utility. When we are told, that searching for shell-fish, and conveying them to the market, give employment to a British population of upwards of 10,000; that these animals furnish nourishing food to innumerable families, and in years of scarcity prevent the horrors of famine; we will be disposed to regard with a favourable eye the labours of that naturalist who examines the structure and economy of those animals, that, from a knowledge of their nature, he may render them still more subservient to our purposes.

Shells as objects of amusement. Even when considered as objects of amusement, molluscous animals are not devoid of interest. In the preceding

division of our subject, we have considered them as applicable to various useful purposes, and expressed our regret, at the same time, that no one qualified for the task had ever bestowed on economical conchology an attentive examination. We cannot therefore consider the present condition of the science as the result of the labours of its practical admirers. The lovers of this study, as an agreeable amusement, have at all times been numerous, from the days of Lælius and Scipio to the present time; and it is to their exertions as collectors, that the science is principally indebted for its present state of improvement. The colours of shells are often so intensely vivid, so finely disposed, and so fancifully variegated, that, as objects of beauty they rival many of the esteemed productions of the vegetable kingdom. In their forms they likewise exhibit an infinite variety. While some consist merely of a hollow cup or a simple tube, others exhibit the most graceful convolutions, and appear in the form of cones, and spires, and turbans; and in another division, shaped like a box, all the varieties of hinge are exhibited, from that of simple connexion by a ligament to the most complicated articulation. The forms of shells are indeed so various, and many of them so elegant, that a celebrated French conchologist warmly recommends them to the attentive study of the architect. "Or," says Lamarck, "comme l'extrême diversité des parties protubérantes de la surface de ces coquilles, ainsi que la régularité et l'élégance de leur distribution, ne laisse presque aucune forme possible dont la nature n'offre ici des exemples; on peut dire que l'architecture trouveroit dans les espèces de ce genre (*Cerithium*) de même que dans celles des pleurotomes et des fuseaux, un choix de modèles pour l'ornement des colonnes, et que ces modèles seroient très dignes d'être employés." (*Annales du Mus.* vol. iii. p. 269.) In this country, however, no such recommendation is necessary, as many of our beautiful ornaments of stucco, particularly for chimney-pieces, are copied from the univalve testacea, and are greatly admired.

But shells, even with all their beauty and elegance, would never have acquired so much importance in the eyes of amateurs, had their forms been as difficult to preserve as the external coverings of the higher classes of animals. It is both a tedious and a difficult operation to preserve a quadruped, a bird, or a fish, as a specimen for the cabinet, and even when the task is completed, it is but of temporary duration. A slow but certain process of dissolution is going on, which, though invisible for a time to the owner, gradually destroys the finest collection of these objects. The very changes of the atmosphere, combined with the attacks of insects, accelerate the destructive process. But with shells the case is very different. Composed of particles already in natural combination, they do not contain within themselves the seeds of dissolution, so that for ages they remain the same. Besides, all that is in general necessary to prepare a shell for the cabinet, is merely to remove the animal. When the shell is covered with foreign matter, we must wash it away with a brush in soap in water; and it is frequently necessary to steep the shell for some time in fresh water, to extract all the salt water which may adhere to it. After being properly dried it is fit for the shelf of the cabinet, and stands in no need of anxious superintendence.

Amateurs are seldom contented with the simplicity of nature. Polishing. Vitiating in their taste by a fashion which abides by no rules, they attempt to improve even her most elegant productions, and delight to exhibit in their cabinets some of the efforts of their art. As such are in search of innocent amusement, we mean not to dispute about the propriety of their conduct, but rather shortly to mention, for their edification, the method generally in use to improve the beauty of testaceous objects. Many shells, it is true, naturally possess so fine a polish, that no preparation is considered as necessary before placing them in the cabinet. Such are the

Mollusca. Cypræa, Oliva, and the greater number of what is termed *porcellaneous shells*. In general, however, it happens that, when shells become dry, they lose much of their natural lustre. This may be very easily restored, by washing them with a little water, in which a small portion of gum arabic has been dissolved, or with the white of an egg. This is the simplest of those processes which are employed, and is used not only by the mere collector, but by the scientific conchologist. There are many shells of a very plain appearance on the outside, by reason of a dull epidermis or skin with which they are covered. This is removed by soaking the shell in warm water, and then rubbing it off with a brush. When the epidermis is thick, it is necessary to mix with the water a small portion of nitric acid, which, by dissolving a part of the shell, destroys the cohesion of the epidermis. This last agent must be employed with great caution, as it removes the lustre from all the parts exposed to its influence. The new surface must be polished with leather, assisted by tripoli. But, in many cases, even these methods are ineffectual, and the file and the pumice-stone must be resorted to, in order to rub off the coarse external layers, that the concealed beauties may be disclosed. Much address and experience are necessary in the successful employment of this last process. But it must be confessed that the reward is often great. When thus prepared, even the common mussel is most beautiful.

The arrangement of shells in a cabinet must depend, in a great degree, on the taste and fortune of the collector. If ornament is the object in view, it will be indispensably necessary to have the shells placed in glass cases, where they may be distinctly seen. But where a collection of shells is formed for amusement, they may be kept in drawers, each species placed in a paper case, or in a cup of wood, glass, or porcelain, with a label attached, intimating its name, and the place from whence it was obtained. In this manner, both univalves and bivalves may be conveniently disposed. But as many of the former are very small in size, it is often necessary to fix them on pieces of card, that they may be preserved, and rendered easier of inspection. When neighbouring species are thus brought together, they can be easily examined with a lens.

About the end of the sixteenth century, many individuals began to form collections of testaceous bodies. The first museum of this kind, of any consequence, was begun by Benedict Ceruto, and afterwards augmented by Calceolari. An account of the specimens contained in it was published by Olivi, in 1585, and, in 1622, Chiocco published plates of the shells. After this period, in proportion as collections of testaceous bodies became numerous, various works on shells made their appearance. These were not published for any scientific object, but merely to teach collectors the names of the different specimens in their museums. As works of this sort, we may mention the *Historia Naturalis* of Johnston; the *Gazophylacium Naturæ* of Petiver; the *Amboinshe Rariteitkamer* of Rumphius; and the *Wondertooneel der Nature* of Vincent. To this list we might add many modern works, which are termed Systems of Conchology.

From the labours of this class of conchologists the science has derived many important advantages. A taste for the study has been widely extended; the shells of distant countries and shores have been brought together; and numerous engravings of these bodies have been published. In this manner the labours of the man of science have been greatly facilitated, and our knowledge of nature enlarged.

Formation of a collection of shells. The formation of a collection of shells is absolutely necessary to the successful prosecution of the science of conchology. To accomplish this, much care and attention are requisite. Shells must be sought for in their natural situations, and obtained, if possible, with the animal alive. After the animal has remained dead in the shell for any length of time, it loses its lustre and transparency, and becomes less

valuable, either as an object of beauty or curiosity. Hence the collector must explore the sea-coast, the land, and the fresh water, in search of the testaceous animals which they support, for the purpose of obtaining in a perfect state their calcareous coverings.

The sea contains more species of shells than either the land or the fresh waters, and presents to the conchologist an extensive field for observation. Many species of marine shells frequent the sea-shore, adhere to rocks, stones, or sea weed, or lodge in the clay or sand. These are termed *Littoral* shells, and are seldom found in deep water. The littoral shells are easily collected at ebb tide. Those which burrow in the mud or sand may be detected by a small depression which they leave on the surface as they retire below it. Other shells live in deeper water. To collect these the dredge must be employed; and if the shells be put into sea water after they are brought up, the animals may afterwards be examined with ease. Such collectors as have not the advantage of a dredge, should examine the refuse of fishing boats, and traverse the sea shore, and search the rejectamenta, especially after a storm of wind. The roots of the larger *Fuci*, especially *F. digitatus*, which grows sometimes in four or five fathoms water, frequently contain a treasure of the rarer shells.

During the ebb of stream tides, the conchologist ought to be very diligent. The rocks are then uncovered, and under the projecting ledges of the strata he will find many species of shells in very perfect state.

In rocky shores it will prove a useful employment to turn over the stones which are scattered in the pools, near low water, and on the under side of these he will find a rich harvest of Chitons and Cingulæ.

In the tufts of *Corallina officinalis*, a number of the smaller shells are found concealed, likewise among the smaller *Fuci* and *Confervæ*. When these bodies are brought from the shore, and put into a glass of sea water, the smaller shells will soon be perceived by their motions.

When vessels which have been long at sea come into dock to be cleaned, their bottoms are often covered with shells, and with sea-weed, containing numerous rare vermes. To such situations the conchologist should resort; and in these he will often be successful in finding the objects of his pursuit. In illustration of this remark, we may mention the circumstance of the vessel employed at the Bell Rock as a floating light, having had her bottom covered with mussels three inches and a half in length, and upwards of one inch in breadth, although she had only been afloat three years and seven months. She was moored the 11th July 1807, and removed the 11th February 1811. Previous to being moored, she was completely caulked and pitched. The sand on the shore likewise yields many of the smaller species of shells, and should be carefully examined with the microscope.

When sea shells are obtained, they should be plunged into boiling water, to facilitate the extraction of the animal, and afterwards soaked in it for some time to remove the salt. They should then be cleaned with a brush, and all extraneous matter removed. When the shells are not soaked in fresh water, the salt remaining soon attracts moisture, which speedily destroys the ligaments and epidermis.

The land shells are more within the reach of the scientific collector. To obtain these, he has only to examine the crevices of rocks, the trunks of trees, decayed wood, moss, and brushwood. In summer, after a shower, the land shells are most easily procured. The animals come forth to feed on the moistened blade, and at that time, from their motion, may be very readily perceived.

The land shells are very easily preserved. Almost all that is required is the extraction of the animal.

The fresh water shells, though less difficult to procure than the sea shells, require more trouble than the land shells. A

Mollusca. piece of gauze spread over a ring attached to the end of a staff, forms a very convenient net for fishing fresh water shells. By means of this net in the drought of summer, almost all the different species of fresh water shells may be obtained with ease.

The fresh water shells are frequently covered over with slime or mud, which must be removed by a brush; and the animal may be extracted after the shell has been plunged in boiling water.

Before closing our remarks on the important group of animals to which we have been directing the attention of the reader, we shall dedicate a few paragraphs to a brief notice respecting FOSSIL SHELLS.

Besides the shells which are found on the land and in our lakes, rivers and seas, and termed RECENT SHELLS, there are relics of many species found in our marl pits and limestone rocks, always somewhat altered, and which are denominated FOSSIL SHELLS. While the shells of the former class have been eagerly sought after, few conchologists, previous to the beginning of the present century, directed their attention to the condition and distribution of the fossil species. Nearly six hundred species of recent shells have been described as natives of Britain, while the fossil species furnished by the strata of the different formations, and which have been accurately described, fall greatly short of that number. There is, however, reason to believe that the fossil species are even more numerous than the recent ones.

It would have been a pleasant task for us to have entered into the details of this most important subject, but our limits permit us only to trace its outlines. Our remarks, however, we trust, will prove useful to those who are entering this fruitful field of investigation, and will embrace some observations on the systematic characters, condition, situation, and distribution of these organic remains.

SYSTEMATICAL HISTORY OF FOSSIL SHELLS.—The determination of the characters of fossil shells is attended with no inconsiderable amount of difficulty. The changes which they have undergone, and their union, in many cases, with the substance of the rock, having become incorporated with it, prevent us from ascertaining, with any degree of accuracy, the peculiar marks by which the species can be characterised. No trace of the animal remains to aid us in the investigation, so that all our distinctions must depend upon the characters furnished by the shell. This circumstance should prevent us from placing much confidence on the conclusions which have been drawn with respect to the resemblance between fossil species, and those which still exist in a living state.

The difficulty of determining the fossil species, and the reluctance to form new genera, rendered the descriptions of the older writers nearly unintelligible, although their figures are still useful to refer to. Lamark, aware of the imperfection of the characters of the genera of recent shells, as connected with this subject, and possessing a rich cabinet of the fossil species found in the neighbourhood of Paris, devoted much time to the illustration of this subject, and with great success, as his various papers published in the *Annales du Museum*, abundantly testify. In this country, Parkinson, in his work entitled *Organic Remains of a Former World*, has added some important illustrations of the genera of Lamark, and has given some good descriptions of the species found in our rocks. Mr. Sowerby, in his *Mineral Conchology*, (published in numbers), has given excellent figures of the British fossil shells; but we regret to add, that he has displayed too great anxiety to constitute species; and that the rocks in which they are found imbedded are but imperfectly characterised. But as the figures are well executed, they will prove highly useful to the British mineralogist, by enabling him to refer to them with confidence, and to give names to those species which he meets with in the course of his investigations.

Mollusca. CHEMICAL HISTORY OF FOSSIL SHELLS.—When we consider the elements of which shells are composed, and the nature of their combination, we might be ready to expect that fossil shells would differ but little in structure from recent species. But the case is widely different. In many instances the confused foliaceous structure which prevailed in the recent shell, has given place to a new arrangement of the particles, and the fossil shell exhibits a foliated crystalline structure. Here solution and precipitation have taken place in the same spot, or the results have been effected by the slow operation of the corpuscular forces. In some cases the calcareous matter of the shell has become impregnated with foreign ingredients, or has totally disappeared, leaving in its place ferruginous or siliceous depositions. But the most curious circumstance in the chemical history of these fossils, is the preservation of the animal matter of the shell in its original form and order of arrangement, even when the calcareous matter of the shell has been changed into compact or granular limestone. This very important fact we owe to the ingenuity of Mr. Parkinson, who, by treating the shell for a length of time with greatly diluted acid, abstracted the calcareous matter, and obtained a distinct view of the cartilaginous membranes of the shell. The student will in general observe, that the cavities of those shells, which present an external opening, are filled with the same sort of matter as the rock in which they are enclosed, while the cavities, of the multilocular testacea, for example, which have no external communication, are filled with matter invariably of a crystalline structure, even when not different from the substance of the rock.

GEOGNOSTIC HISTORY OF FOSSIL SHELLS.—It appears evident that the advancement of this branch of conchology must, in a great measure, depend on the accurate discrimination of the fossil species, and the relations of the rocks in which they are contained. It is only within the last twenty years, therefore, that our knowledge of this branch of the subject has been acquired. The members of the Wernerian and geological societies have contributed largely to our stock of knowledge: but much yet remains to be brought to light. The following notices may be regarded as embracing the principal facts which have been ascertained.

In those ancient strata upon which all the others are incumbent, and which are called *primitive*, no remains of shells, or other relics of organized bodies, have hitherto been detected. These rocks are therefore supposed to have received their arrangement previous to the creation of animals and vegetables, or to have been so much altered as to have all traces of organisms obliterated if such existed. In that group of rocks which rests upon the primitive strata, and to which mineralogists give the name of *transition*, fossil shells, as well as the remains of vegetables, have been observed. The shells exhibit such striking peculiarities of form, and bear so remote a resemblance to the recent kinds, that they are considered as the remains of species which do not now exist in a living state on the globe. They are much changed in their texture, and in general intimately united with the contents of the stratum. They are chiefly found in the beds of limestone, sometimes also in the greywacke and clay slate. In the numerous and ill-characterised series of strata which are incumbent on the transition class, and to which some mineralogists attach the term *floetz*, the remains of shells are much more numerous. In the older members of this class, such as the red sandstone and independent coal formations, the shells, though in a few instances different in form from those of the preceding class, appear to have belonged to one epoch. They are dissimilar to the recent species, and no longer exist in a living state. In the newer members of this class, such as the gypsum and chalk rocks, the species, in some examples, bear a much closer resemblance to the existing races, and several species cannot be distinguished, it is alleged, from them, by any satisfactory characters furnished by

Mollusca. the shell. The fossil species found in the rocks of the older members of the class are greatly altered in their texture, and, in many cases, intimately united with the substance of the beds; the shells belonging to the newer members are much less altered in their form and texture, separate more readily from the surrounding rocks, and appear like recent shells somewhat weathered. The shells are found in nearly all the different kinds of rock, but are more numerous in the calcareous strata. In the *recent* or superficial strata, fossil shells are frequently to be met with. The species which here present themselves bear so close a resemblance to the existing kinds, that conchologists are disposed to consider them as the relics of animals which still exist. In many cases, the prototypes may be found on the neighbouring shore or lake, but in other instances they must be sought for at a greater distance. These shells are found in beds of gravel and sand, and likewise in great abundance in shell marl.

It appears, then, that the shells in the older strata differ specifically from those which the newer strata contain; and that they have belonged to molluscous animals, which no longer exist in a living state on this globe; that, in the newer strata, the fossil shells bear a closer resemblance to existing species; and that in the last formed strata, remains of species actually existing are to be met with.

In this geological distribution of the remains of testaceous animals we may likewise perceive that, in the older strata, the inequivalved shells are more numerous than the other kinds; and that the canaliculated univalves are seldom, if ever, to be met with in the transition or older members of the Floetz series, but that they become more numerous in the newer members of the Floetz rocks, and in the alluvial strata. Circumstances of this kind have induced geologists to conclude that different formations could be discriminated by the petrifications which they contain. From the difficulty of distinguishing the fossil species, however, joined with our ignorance of their geographical distribution, some mineralogists have not permitted their conclusions to be much influenced by this rule.

It will likewise be observed, that the shells in the newer strata are but little changed, whilst those in the older rocks are greatly altered in their texture, and in part obliterated. The same power which rendered the rock compact or crystalline, has likewise exerted its influence on the imbedded remains. In the newest strata, this power has scarcely begun to operate; so that the imbedded shells still retain in perfection their original characters.

In examining a limestone quarry, for example, the student will perhaps be surprised to find petrifications of shells in the bed of limestone, while, in the sandstone covering, he witnesses impressions of plants unaccompanied with shells. In order to gain more correct ideas on this subject, let him repair to a marl bog, and he will there find the bed of marl abounding in shells, while in the bed of sand below, on which it rests, or of peat moss, which covers it, he will find exclusively the remains of vegetables. Here let him study the subject, while the strata are yet recent, and while lapidification is only commencing. There is, however, this difference between the shells in the marl and those in the limestone, that individuals of the former species still exist, while no living examples of the latter are known.

GEOGRAPHICAL HISTORY OF FOSSIL SHELLS.—As the geographical distribution of recent shells is a branch of conchology to which few have devoted their attention, and about which very little is known, we can scarcely expect to find the geographical distribution of the fossil species more fully illustrated. We know, with regard to the recent shells, that some species which are found in the bays of Norway and Greenland occur also on the shores of the Mediterranean, and that the British Isles have several species in common

with Africa and the West Indies. Still we know not, with *Mollusca.* any degree of accuracy, the geographical range of any one species. Geologists ought, therefore, to exercise a great degree of caution in drawing conclusions concerning the original situation of those shells which they find in a fossil state. When a fossil shell is discovered in the strata of this country, which bears a close resemblance to the recent shells of distant seas; many inquirers, without waiting until they have established the identity of the species, and without any precise information with regard to the geographical distribution of that species, conclude that this fossil shell must have been brought from these distant seas, and conveyed to its present situation by some mighty torrent. Instances of this mode of reasoning could easily be pointed out in the writings of British and Continental mineralogists.

In every country there are particular animals and vegetables, which indicate, by their mode of growth and rapid increase, a peculiar adaptation to the soil and climate of that district. Hence we find a remarkable difference in the animals and plants of different countries. Many shell-fish have indeed a very wide range of latitude, through which they may be observed; but we know, that the same molluscous animals which are natives of Britain, are not found, as a whole, as natives of Spain, while the molluscous animals of Africa differ from both. If the same arrangement of the molluscous animals always prevailed in the different stages of their existence, then we may expect to find the fossil shells of one country differing as much from those of another, as the recent kinds are known to do, so that every country will have its *fossil*, as well as its *recent* testacea. Few observations illustrative of this branch of the subject have hitherto been published.

It has often been remarked, that the fossil shells (and the relics of other animals and plants) found in the strata of this country, are very different in their appearance from those shells of the mollusca which at present exist in the country, but that they bear a close resemblance to the existing species of the equatorial regions. This very important observation has led some to conclude, that the mollusca which lived in this country at the period of the formation of the strata in which they are now enclosed, were influenced by different physical circumstances, from those by which the forms of the recent kinds are regulated; while others have imagined that those shells once lived in the equatorial regions, and that a mighty deluge transported them to their present situation. This last conclusion can never be admitted by those who have witnessed the perfect preservation of the different parts of fossil shells, their valves, spires, protuberances, and delicate spines, still unbroken. Though these species no longer exist in a living state in this country, nor on the globe, we must admit the conclusion of Werner, with regard to fossil plants, that they lived and died in the country where their relics are now found.

It would form a very curious subject of inquiry to ascertain the character of those fossil shells which are found in the strata near the equator. If they likewise differ from the recent species of those seas, and if, in appearance, they resemble or differ from the productions of arctic regions, we might then speculate, with more success, upon those mighty revolutions which have taken place on the earth's surface, and trace in the mineral kingdom the proofs of those changes which animals and vegetables have experienced. In the meantime, we would recommend the examination of the laws which regulate the physical and geographical distribution of recent shells and molluscous animals, as the most suitable preparation for investigating the condition of those extinct races, the memorials of which are preserved in strata, differing from one another in structure, in position, and in composition.

Moloch
||
Molossi.

DESCRIPTION OF THE PLATES.

- PLATE I.—*Spirula australis*, fig. 1.—*Octopus cirrhosus*, fig. 2.—*Argonauta Argo*, fig. 3.—*Nautilus umbilicatus*, fig. 4.—*Hyalea globosa*, fig. 5.—*Pneumodermon diaphanum*, fig. 6.—*Clio borealis*, fig. 7.—*Cleodora lanceolata*, fig. 8.—*Cymbulia Peronii*, fig. 9.
- PLATE II.—*Achathina fasciata*, fig. 1.—*Helix Cepa*, fig. 2.—*Auricula Midæ*, fig. 3.—*Ampullaria virescens*, fig. 4.—*Testacilla Maugii*, fig. 5.—*Testacilla haliotoidea*, fig. 6.—*Limnea octanfracta*, fig. 7.—*Segmentina lineata*, fig. 8.—*Planorbis nitidus*, fig. 9.—*Ancylus lacustris*, fig. 10.
- PLATE III.—*Scyllea pelagica*, fig. 1.—*Tritonia Hombergii*, fig. 2.—*Glaucus radiatus*, fig. 3.—*Dolabella Rumphii*, fig. 4.—*Chiton squamosus*, fig. 5.—*Fissurella annulata*, fig. 6.—*Parmophorus australis*, fig. 7.—*Bulla aperta*, fig. 8.
- PLATE IV.—*Trochus Pagodus*, fig. 1.—*Turbo rugosus*, fig. 2.—*Na-*

tica plicata, fig. 3.—*Velutina lævigata*, fig. 4.—*Delphinula calcar* of Lamark, fig. 5.—*Delphinula Lima*, fig. 6.—*Scalaria pretiosa*, fig. 7.—*Solarium hybridum*, fig. 8.—*Paludina vivipara*, fig. 9.—*Buccinum lævissimum*, fig. 10.

- PLATE V.—*Voluta Japonica*, fig. 1.—*Terebra crenulata*, fig. 2.—*Harpa ventricosa*, fig. 3.—*Cassis decussata*, fig. 4.—*Turbinella pyrum*, fig. 5.—*Fasciolaria traperium*, fig. 6.—*Pyrula perversa*, fig. 7.—*Fusus retroversus*, fig. 8.—*Fusus servatus*, fig. 9.—*Murex haustellum*, fig. 10.—*Scissurella crispata*, fig. 11.
- PLATE VI.—*Terebratula cranium*, fig. 1.—*Diceras arictina*, fig. 2.—*Unio pictorum*, fig. 3.—*Crossatella sulcata*, fig. 4.—*Cyclas cornea*, fig. 5.—*Lingula anatina*, fig. 6.—*Anatina hispidula*, fig. 7.—*Teredo navalis*, fig. 8.
- PLATE VII.—*Clavellina lepadiformis*, fig. 1.—*Ciona intestinalis*, fig. 2.—*Ascidia N. S. Lister*, fig. 3.—*Botryllus polycyclus*, fig. 4.—*Boltenia ovifera*, fig. 5.—*Cynthia momus*, fig. 6.—*Phallusia nigra*, fig. 7.—*Salpa cristata*, fig. 8.

Molton,
South
||
Mona.

MOLOCH, a false god of the Ammonites, who dedicated their children to him, by making them pass through the fire, as the Scriptures express it. There are various opinions concerning this method of consecration. Some think that the children leaped over a fire sacred to Moloch; others are of opinion that they passed between two fires; and others conceive that they were really burned in the fire by way of sacrifice to this god. There is some foundation for each of these opinions. For, in the first place, it was usual amongst the Pagans to lustrate or purify with fire; and next, it is expressly said, that the inhabitants of Sepharvaim burned their children in the fire to Anamelech and Adramelech, deities similar to the Moloch of the Ammonites.

Moses, in several places, forbids the Israelites to dedicate their children to this god, as the Ammonites did, and threatens death and utter extirpation to such persons as should commit this abominable idolatry. There is great probability that the Hebrews were much addicted to the worship of this deity; since Amos, and after him St Stephen, reproaches them with having carried along with them into the wilderness the tabernacle of their god Moloch.

Solomon built a temple to Moloch upon Mount Olivet; and Manasseh, long afterwards, imitated his impiety by making his son pass through the fire in honour of Moloch. It was chiefly in the valley of Tophet and Hinnom, to the east of Jerusalem, that the Israelites paid their idolatrous worship to this false god of the Ammonites.

There are various sentiments concerning the relation which Moloch bore to the other Pagan divinities. Some believe that he was the same with Saturn, to whom it is well known that human sacrifices were offered; others suppose him to be Mercury; others confound him with Mars, Mithras, and Venus; and others, again, take Moloch for the Sun, or the king of heaven. Moloch was likewise called *Milcom*, as appears from what is said of Solomon, that he went after Ashtaroth the abomination of the Zidonians, and *Milcom* the abomination of the Ammonites.

MOLOSSES, **MOLASSES**, or *Melasses*, the gross fluid matter of sugar remaining after refining, and which no boiling will bring to a consistence more solid than that of syrup. Properly, molasses are only the sediment of one kind of sugar called *chypre*, or brown sugar, which is the refuse of other sugars, and cannot be whitened or reduced into loaves. Molasses are much used in Holland for the preparation of tobacco, and also amongst poor people instead of sugar. There is a kind of brandy or spirit made of molasses; but it is held by some to be exceedingly unwholesome.

MOLOSSI, a people of Epirus, who inhabited that part of the country which was called *Molossia*, from Molossus,

a son of Pyrrhus and Andromache, the king of the country. Molossia had the Bay of Ambracia as its boundary on the south, and the country of the Perrhæbeans on the east. The dogs of this country were famous, and received the name of *Molossi* amongst the Romans. Dodona was the capital of the country, according to some writers; but others think that it was the chief city of Thesprotia.

MOLTON, SOUTH, a town of the county of Devon, in the hundred of its own name, 179 miles from London. It stands on the river Mole or Mould, and has some trade in making serges, shalloons, and other woollens. It is an ancient corporation, and formerly sent two members to parliament. It has a well-supplied market, which is held on Saturday, and also five fairs. The population amounted in 1801 to 2753, in 1811 to 2739, in 1821 to 3314, and in 1831 to 3826. About two miles from it is the parish or town of North Molton, the population of which amounted in 1801 to 1541, in 1811 to 1526, in 1821 to 1847, and in 1831 to 1937.

MOLUCCA ISLES. These islands were formerly understood to signify all the islands situated to the east of the Molucca passage, in longitude 126° east, particularly those of Gilolo; but in general the term has been restricted to the Spice Islands, namely, Amboyna, Banda, Ceram, Ternate, Tidore, and Batchian. These islands, which are famous for the production of spices, particularly nutmegs and cloves, were first, in 1510, visited by the Portuguese, who took possession of them, and whose right was contested by the Spaniards. They succeeded, however, in acquiring possession of them, but were conquered by the Dutch in 1607. These islands were taken from the Dutch by the British during the French revolutionary war, but restored at the peace.

MOMUS, in fabulous history, was the god of railery, or the jester of the celestial assembly, who ridiculed both gods and men. Being chosen by Vulcan, Neptune, and Minerva, to give his judgment concerning their works, he blamed them all; Neptune for not making his bull with horns before his eyes, in order that he might give a surer blow; Minerva for building a house which could not be removed in case of bad neighbours; and Vulcan for making a man without a window in his breast, that his treacheries might be seen. For the freedom of his reflections upon the gods, Momus was expelled from heaven. He is generally represented as raising a mask from his face, and holding a small figure in his hand.

MONA, in *Ancient Geography*, is a name applied to two islands in the sea between Great Britain and Ireland. The one, described by Cæsar as situated in the middle passage between both islands, called *Monaæda*, *Monapia*, or *Monabia*, is supposed to be the Isle of Man. But there was

Mona another Mona, an island more to the south, separated from the coast of the Ordovices by a narrow strait. This was the ancient seat of the Druids, and is now called *Anglesey*, the island of the Angles or English.

MONA and MONITA, that is, The Monkey and his Cub, two islands of the West Indies, in the middle of the great passage between Hispaniola and Porto Rico. The Mona Isle measures seven miles one way and two another; and, although once in good cultivation, is now only the solitary range of wild goats.

MONACO, a province of Sardinia, but formerly an independent principality, now reduced to the condition of a mediatised state, to the prince of which his rents are preserved. It extends over fifty-five square miles, and contains two cities, with about 6000 inhabitants. The district is sheltered from cold winds, which makes the climate like that of the tropics; and the productions of the soil are similar, fruit being abundant, but corn deficient, and flesh rather more so. It was seized by France in 1792, and added to one of her departments; but, by the congress of Vienna in 1815, it was transferred to Sardinia. The chief place, of the same name, is situated on a tongue of land running into the sea. The walls and gates are dilapidated. It contains 1250 inhabitants, employed in petty trade. Long. 7. 23. E. Lat. 43. 44. N.

MONADELPHIA (from *μονος*, alone, and *ἀδελφία*, a brotherhood), a single brotherhood, the name of the sixteenth class in Linnæus' sexual system, consisting of plants with hermaphrodite flowers; in which all the stamina are united below into one body or cylinder, through which passes the pistillum. See BOTANY.

MONAGHAN, an inland county in the province of Ulster, in Ireland, is bounded on the north by the county of Tyrone, on the east by those of Armagh and Louth, on the south by those of Louth and Cavan, and on the west by those of Cavan and Fermanagh. It extends over a surface of 327,048 acres, of which 309,968 acres are capable of cultivation, 9236 are unprofitable mountain or bog, and 7844 are under water.

According to Whitaker, the tribe of the Scoti, which spread itself over the greater part of the interior of Ireland, inhabited this county in the time of Ptolemy. In a subsequent period of Irish history it formed part of the territory of Uriel or Orgial; and, from the principal family which then resided in it, was also known by the name of M'Mahon's country. In the reign of Elizabeth it was reduced into shire-ground, and was divided into the five baronies which still exist, namely, those of Cremorne, Darry, Farney, Monaghan, and Trough. These are subdivided into nineteen parishes, and four parts of parishes, the remainder of which are in some of the adjoining counties.

According to the ecclesiastical arrangements of the country, Monaghan is wholly included in the diocese of Clogher, the see of which is in the city of the same name in the county of Tyrone. It contains twenty-one parishes.

The general appearance of the surface is hilly, yet not rising into heights of considerable elevation. Its principal mountain range is that of Slievebaugh, a rugged and barren tract which separates it from Tyrone. Its highest summit, called Cairnmore, commands an extensive view of the surrounding country on every side. Crieve Mountain, in the south, is still more elevated, but of smaller superficial extent. There are no rivers of any consequence. The Finn, which rises near the centre of the county, scarcely merits the title of river until after its entrance into Fermanagh; and the Blackwater, forming part of the north-eastern boundary towards Tyrone, is the receptacle of many of the smaller rivulets which take their rise here. But, though deficient in rivers of magnitude, it is amply furnished with streams of running water, well suited to the purposes of agriculture and of manufacturing industry; nor

can any other county boast of such a number of lakes, although few of them are of an extent such as to entitle them to specific notice. The number of these lakes is 184, thirty of which are considerable sheets of water. The most remarkable are Lough Eagish, on Crieve Mountain, which supplies water for a long succession of mills and bleaching-greens; Lakes Damby, Camm, and Oona. Others near Castleblaney, Dawson Grove, and Mount Lewis, are celebrated for the beauty of the surrounding scenery.

The soil is of various kinds. In the central parts it consists of a rich limestone. The southern districts are partly of the same quality, and partly a deep clay, capable of a high degree of cultivation under judicious management. The north consists mostly of a stiff retentive clay, marshy in winter, and hardening quickly by the heat of summer, yet interspersed in many parts with tracts of valuable limestone soil. Whilst the limestone formation predominates in the level districts, the more elevated portions exhibit traces of a different character. To the north the hills show sandstone; but those in the south are of basalt or whinstone. Coal has been found in more than one place, but in veins so poor and scanty as not to encourage the outlay of capital upon its exploration. Slates of good quality are quarried in Crieve Mountain. A lead mine was also worked there, but has long since been relinquished as unprofitable. Ochre, potters' clay of such quality as to cause an exportation of it to Dundalk for the manufacture of glazed earthenware, brick clay, manganese, antimony, and fullers' earth, are also found here. There is a chalybeate spring at Drumtubberbuy, on Cairnmore, the water of which casts up a thick scum of ochre. A well near Clones is much celebrated for its efficacy in cases of jaundice, whence it has acquired its name of Granabuymore, or "the great yellow cure." A spring at Tullaghan throws up water which, although perfectly tasteless and clear, deposits an incrustation on the banks near its source. This county has a large proportion of bog, which, together with its great number of lakes, and its exposure to the north-western winds, render it very damp, although it is far from being unwholesome.

The results of inquiries as to the population, made at different periods, are as follow:

Year.	Authority.	Population.
1760.....	De Burgo.....	49,848
1792.....	Beaufort.....	118,000
1812.....	Parliamentary return.....	140,433
1821.....	Ditto.....	174,697
1831.....	Ditto.....	195,521

The comparison of the amount of population, according to the latest of these returns, with the superficies of the county, gives a result of one individual to every acre and a half.

This population was represented in the Irish parliament by four members; two for the county at large, and two for the borough of Monaghan. Those for the borough were struck off at the period of the Union; and no alteration to the arrangement then made has taken place under the reform act.

The constituency, as it was constituted at three periods, viz. 1st, previously to the disqualification of the forty-shilling freeholders; 2d, subsequently to their disqualification; and, 3d, under the reform act, exhibits the following changes:

Year.	L.50.	L.20.	L.10.	40s.	Total.
1st Jan. 1829.....	300.....	107.....	—	12,453.....	12,860
1st Jan. 1830.....	322.....	194.....	632.....	—	1,148
1st May 1831.....	464.....	254.....	946.....	—	1,664

The local government is vested in a lieutenant, fourteen deputy-lieutenants, and sixty-one magistrates, who are supported by a constabulary force, consisting of four chief and eighty sub-constables. The constabulary establishment is maintained at an expense of about L.4000, being at an

Monaghan. average of somewhat more than L.47 per annum for each man. Under the provisions of the new constabulary act, this force consists of a sub-inspector, five chief constables, and ten head constables, with eighty constables and sub-constables.

The state of education, as collected from the parliamentary returns made in 1821 and 1831, is shown in the following table. The returns made by the commissioners of public instruction in 1834 cannot be stated, in consequence of their having been made up according to dioceses instead of counties :

Year.	Boys.	Girls.	Sex not ascertained.	Total.
1821.....	4517.....	2743.....	—	7,260
1824-6.....	6694.....	4205.....	320.....	11,219

Of the numbers stated in the latter of these returns, 2471 were Episcopalian Protestants, 2166 Protestant Dissenters, and 6408 Roman Catholics ; the religious persuasion of 174 was not ascertained. The proportion of Protestants to Roman Catholics, as far as can be inferred from the relative numbers of the children of each religious persuasion attending public schools, is as two to three nearly. The total number of schools was 281 ; of which 19, containing 1006 children, were supported by grants of public money ; 37, containing 2551 children, were supported by the voluntary contributions of societies or individuals ; the remaining 225 schools, which afforded the means of education to 7662 children, were maintained wholly by the fees of the pupils. The diocesan school of the see of Clogher is in the town of Monaghan. There is also an endowed school at Carrickmacross.

The population is chiefly rural, dispersed either in detached dwellings throughout the country, or in small villages. The total number of residents in towns containing upwards of one thousand inhabitants each, is only 13,000, out of a population which may be stated in round numbers at 200,000 ; and there are but five towns of this description, so that their average population is but 2600 souls each.

The estates in land are of every value, from L.20,000 per annum to L.20 ; being partly held under grants of the escheated lands in Ulster in the time of James I., and partly arising out of the forfeitures in the time of Cromwell. Leases are for short terms, usually twenty-one years, and one or three lives. The mountainous districts are frequently held in joint tenancy by a large number of occupants. The tenants of one of those mountain districts once formed a community of very singular character. Their village consisted of nearly two hundred cabins, on a tract of 500 acres of bog, at Blackstaff, near Carrickmacross, but so barren as not to afford the means of the lowest animal subsistence, so that they were forced to derive their support from patches of land rented by them at a considerable distance from their place of residence. The community allowed itself to be governed by a mayor, chosen annually by all the members. The holder of the largest potato-garden was sure to be elected. All disputes were referred to him, and no appeal was known to be made from his decision. His fee was a bottle of whisky, which was invariably shared by him with the contending parties. The office was one of honour rather than of profit ; for there was no instance of a mayor holding his post for two successive years. The community was broken up in consequence of the rebellion of 1798, at which time the members were compelled to quit their village, and to reside upon their detached plots ; yet, for several years afterwards, they held an annual convivial meeting on the site of their deserted village.

The mansions of the landed proprietors are numerous and elegant ; the houses of the wealthier farmers, and more particularly of those who combine manufactures with agriculture, exhibit every indication of comfort ; but

the dwellings of cottiers and labourers are miserable in the extreme. The dress of the male peasantry is home manufactured frieze, dyed blue ; that of the female generally cotton. Flesh meat seldom forms a part of their dietary. The cottiers in the districts remote from towns are unable to procure any food but potatoes seasoned with salt. Fuel is cheap and abundant, in consequence of the quantity of bog. The language is both English and Irish ; but the latter predominates in the more retired parts of the county.

The state of agriculture has improved with great rapidity during the last twenty or thirty years. The accounts given shortly after the year 1800 describe the old country plough of clumsy construction, the slide-car without wheels, the conveyance of the manure and field produce on horses' or asses' backs, and the application of manual labour and spade-husbandry as being generally prevalent. At present all the improvements introduced by scientific agriculturists are to be seen in practice here, as far as they have been found consistent with the peculiar nature of the soil and climate. Ploughs on the most improved plan, Scotch carts, and implements of various kinds to supersede the improvident exertion of manual labour, are universal ; yet in some parts where the nature of the ground forbids the use of the plough, considerable tracts of land are still cultivated by the spade. The old, stunted, and ill-conditioned breeds of black cattle, sheep, and hogs, have given way to the most esteemed British or foreign stocks, the character of which has not unfrequently been made more suitable to the agricultural localities by judicious crossings with the native breeds. Wheat and oats are the principal species of grain. Barley and bear are largely grown in the hilly districts. Clover is much encouraged, and few farmers are without a patch of it, however small. It is cut green for soil, and is found extremely economical. The tops of furze or gorse are also used, when pounded, as food for horses, and prove highly palatable to the animal, as well as very nutritious. Flax, for the growth of which the soil is peculiarly favourable, is very generally raised. The manure is formed of composts, of which lime and burned turf mould are generally component parts ; marl, though common, is little used. The fences in some parts are of white thorn, interspersed with willows ; in others a slight mound of earth serves rather to determine the boundary than to prevent trespassing. Asses and pigs are numerous. Fish abound in the numerous lakes. The county was once almost a continuous forest, excepting the higher lands, which appear to be of a nature ungenial to the growth of trees. The numerous demesnes of the nobility and gentry are richly embellished by plantations of modern growth. Ash and sycamore are much encouraged. The wood of the latter is in great repute for some parts of mill-machinery. Osieries are frequently to be found in the marshy bottoms at the foot of hills, and prove highly profitable.

The principal manufacture is that of linen, which was long carried on with great spirit, and produced a considerable export ; but it has latterly declined, partly in consequence of the increasing preference given to cotton goods. The woollen manufacture is chiefly employed in supplying the domestic consumption. The sand or gritstone of Cairnmore has given rise to a manufacture of millstones there, which are in considerable demand. Tanyards are frequent. Coarse earthenware is manufactured at Glasslough, and a small iron-work near Clones supplies most of the agricultural implements used in the county.

The remains of antiquity are but few. The most remarkable are two round or pillar towers ; one in the burial-ground of Clones, and the other at Inniskeen, on the borders of Louth. The former consisted of five stories, the traces of which are still visible in the walls ; and its door is about four feet above the level of the ground. Near it is a large stone coffin, above ground, with a cover of the same

Monandria material shaped like the roof of a house. The latter of these towers is in a much inferior state of preservation, and is unique, as having its door upon a level with the surrounding country, although this is supposed by some to be the effect of a modern alteration. Near Clones are two large raths; one in good preservation, exhibiting distinct traces of its fosses and embankments; the other smaller, and much decayed. Danish forts are numerous. The only monastic structure of which any vestiges remain is that of Clones, which was a foundation of regular canons. It was destroyed by Hugh de Lacy, shortly after the arrival of the English; but was rebuilt soon afterwards, and secured from a similar fate by the erection of a castle in its neighbourhood. An abbey of Conventual Franciscans was founded at Monaghan by one of the M'Mahons; but it was afterwards totally destroyed, and a castle erected on its site, which also was in a ruinous state in the reign of James I. Ruins of castles are to be seen at Donaghmoyne and Dawson's Grove.

Monaghan, the county town, is situated near the centre of the county, at a short distance from the Blackwater, to the south. Its ancient name was Muinechan, "the town of Monks," given to it from the religious establishment formerly existing there. The principal buildings are a market-house, in which a brisk linen trade is carried on, erected by Lord Rossmore in 1792; a court-house; and a parish church. In the immediate vicinity of the town is a Roman Catholic chapel, a Presbyterian meeting-house in the New Market, the county infirmary, the diocesan school-house, the barrack for cavalry at the northern entrance of the town, and an extensive county prison, which has been built at an expense of L.20,000. The town contains a brewery, and carries on a pretty considerable trade in linen. Its population in 1831 amounted to 3848 souls. The other towns whose population exceeds 1000 souls are as follow:—Carrickmacross, 2979; Clones, 2381; Ballibay, 1947; and Castleblayney, 1828.

MONANDRIA (from *μονος*, alone, and *ἀνρς*, a man or husband), the name of the first class in Linnæus' sexual system, consisting of plants with hermaphrodite flowers, which have only one stamen.

MONARCHY, a large state governed by one man, or a state where the supreme power is lodged in the hands of a single person. The word comes from the Greek, *μοναρχης*, one who governs alone; formed of *μονος*, solus, alone, and *ἀρχη*, imperium, government. Of the three forms of government, democracy, aristocracy, and monarchy, the last is the most powerful, all the sinews of government being knit together, and united in the hand of the prince; but then there is imminent danger of his employing that strength to improvident or oppressive purposes. As a democracy is best calculated to direct the end of a law, and an aristocracy to invent the means by which that end shall be obtained, a monarchy is most fitted for carrying those means into execution.

The most ancient monarchy was that of the Assyrians, which was founded soon after the Deluge. We usually reckon four grand or universal monarchies; the Assyrian, Persian, Grecian, and Roman; though St Augustin makes them but two, namely, those of Babylon and Rome. Belus is placed at the head of the series of Assyrian kings who reigned at Babylon, and is by profane authors esteemed the founder of that empire; by some he was considered as the same person whom the Scriptures call Nimrod. The principal Assyrian kings after Belus were Ninus, who built Nineveh, and removed the seat of empire to it; Semiramis, who, disguising her sex, took possession of the kingdom instead of her son, and was killed and succeeded by her son Ninyas; and Sardanapalus, the last of the Assyrian monarchs, and more effeminate than any woman. After his death the Assyrian empire was divided into three separate

kingdoms, viz. the Median, Assyrian, and Babylonian. **Monarchy.** The first king of the Median kingdom was Arbaces; and this kingdom lasted till the time of Astyages, who was subdued and divested of his dominions by Cyrus.

In the time of Cyrus there arose a new and second monarchy called the Persian, which lasted upwards of 200 years from Cyrus, whose reign began in the year of the world 3468, to Darius Codomannus, who was conquered by Alexander, and the empire transferred to the Greeks in 3674. The first monarch was Cyrus, founder of the empire; the second, Cambyses the son of Cyrus; the third, Smerdis; the fourth, Darius the son of Hystaspis, who reigned 521 years before Christ; the fifth, Xerxes, who reigned 485 years before Christ; the sixth, Artaxerxes Longimanus, who reigned 464 years before Christ; the seventh, Xerxes the second; the eighth, Ochus or Darius, called Nothus, who reigned 424 years before Christ; the ninth, Artaxerxes Mnemon, 405 years before Christ; the tenth, Artaxerxes Ochus, 359 years before Christ; the eleventh, Arses, 338 years before Christ; the twelfth, Darius Codomannus, who was defeated by Alexander the Great, and deprived of his kingdom and life about 331 years before Christ. After his death, the dominion of Persia was transferred to the Greeks.

The third monarchy was the Grecian. As Alexander, when he died, did not declare who should succeed him, there started up as many kings as there were commanders. At first they governed the provinces, which were divided amongst them, under the title of viceroys; but when the family of Alexander the Great became extinct, they assumed the style and title of kings. Hence, in process of time, the whole empire of Alexander produced four distinct kingdoms. The first was the Macedonian, the kings of which, after Alexander, were Antipater, Cassander, Demetrius Poliorcetes, Seleucus Nicanor, Meleager, Antigonos Doson, Philip, and Perseus, under whom the Macedonian kingdom was reduced to the form of a Roman province. The second was the Asiatic kingdom, which, upon the death of Alexander, fell to Antigonos, comprehending the country now called Anatolia, together with some other regions beyond Mount Taurus. From this kingdom proceeded two lesser ones; that of Pergamus, whose last king, Attalus, appointed the Roman people to be his heir; and Pontus, reduced by the Romans into the form of a province, when they had subdued the last king, Mithridates. The third was the Syrian, of whose twenty-two kings the most celebrated were, Seleucus Nicanor, founder of the kingdom, Antiochus Deus, Antiochus the Great, Antiochus Epiphanes, and Tigranes, who was conquered by the Romans under Pompey, when Syria was reduced into the form of a Roman province. The fourth was the Egyptian, which was formed by the Greeks in Egypt, and flourished near 240 years, under twelve kings, the principal of whom were, Ptolemy Lagus, its founder; Ptolemy Philadelphus, founder of the Alexandrian library; and Queen Cleopatra, who was overcome by Augustus, in consequence of which Egypt was added to the dominion of the Romans.

The fourth monarchy was the Roman, which lasted 244 years, from the building of the city until the time when the royal power was abrogated. The kings of Rome were Romulus, its founder, Numa Pompilius, Tullus Hostilius, Ancus Martius, Tarquinius Priscus, Servius Tullius, and Tarquinius Superbus, who was banished, and with whom terminated the regal power.

There seems in reality to be no necessity for making the Medes, the Persians, and the Greeks, succeed to the whole power of the Assyrians, in order to multiply the number of the monarchies. It was the same empire still; and the several changes which happened in it did not constitute different monarchies. Thus the Roman empire was

Monaster-
evan
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Monastery. successively governed by princes of different nations, yet without any new monarchy being thereby formed. Rome, therefore, may be said to have immediately succeeded to Babylon in the empire of the world.

Fifth-MONARCHY MEN, in the ecclesiastical history of England, were a set of wrong-headed and turbulent enthusiasts, who arose in the time of Cromwell, and expected Christ's sudden appearance upon earth to establish a new kingdom; in consequence of which illusion, they aimed at the subversion of all human government.

MONASTEREVAN, a town of Ireland, in the county of Kildare, situated on the river Barrow, which here intersects the Grand Canal. It is thirty-eight miles south-west from Dublin. The population in 1831 was 1441.

MONASTERY, a convent or house built for the reception of religious, whether it be abbey, priory, convent, or other. This name is only properly applied to the houses of monks, mendicant friars, and nuns. The rest are more properly called *religious houses*.

The houses belonging to the several religious orders which prevailed in England and Wales were, cathedrals, colleges, abbeys, priories, preceptories, commandries, hospitals, friaries, hermitages, chantries, and free chapels. These were under the direction and management of various officers. The dissolution of houses of this kind began as early as the year 1312, when the Templars were suppressed; and in 1323, their lands, churches, advowsons, and liberties, in England, were given, by 17 Edward II. st. 3, to the prior and brethren of the hospital of St John of Jerusalem. In the years 1390, 1437, 1441, 1459, 1497, 1505, 1508, and 1515, several other houses were dissolved, and their revenues settled on different colleges in Oxford and Cambridge. Soon after the last period, Cardinal Wolsey, by license of the king and pope, obtained a dissolution of above thirty religious houses, for the founding and endowing of his colleges at Oxford and Ipswich. About the same time a bull was granted by the same pope to Cardinal Wolsey to suppress monasteries where there were not above six monks, to the value of 8000 ducats a year, for endowing Windsor and King's College in Cambridge; and two other bulls were granted to Cardinals Wolsey and Campeius, to suppress houses where there were less than twelve monks, and to annex them to the greater monasteries; besides another bull to the same cardinals to inquire concerning abbeys to be suppressed in order to be made cathedrals. Although nothing appears to have been done in consequence of these bulls, the motives which induced Wolsey and many others to suppress these houses was the desire of promoting learning; and Archbishop Cranmer engaged in it with a view of carrying on the Reformation. There were other causes which concurred to bring on their ruin. Many of the religious were loose and vicious; the monks were generally thought to be in their hearts attached to the pope's supremacy; their revenues were not employed according to the intention of the donors; many cheats in images, feigned miracles, and counterfeit relics, had been discovered, which brought the monks into disgrace; the Observant Friars had opposed the king's divorce from Queen Catharine; and these circumstances operated, in concurrence with the king's want of a supply and the people's desire to save their money, to forward a motion in parliament, that, in order to support the king's state, and supply his wants, all the religious houses might be conferred upon the crown which were not able to spend above L.200 a year. For this purpose an act was passed, being the 27th Hen. VIII. c. 28. By this act about three hundred and eighty houses were dissolved, and a revenue of L.30,000 or L.32,000 a year accrued in consequence to the crown; besides about L.100,000 in plate and jewels. The suppression of these houses occasioned discontent, and at length an open rebellion. When this was appeased,

the king resolved to suppress the rest of the monasteries, and appointed a new visitation, which caused the greater abbeys to be surrendered apace; and it was enacted by 31 Henry VIII. c. 13, that all monasteries, &c. which have been surrendered since the 4th of February, in the twenty-seventh year of his majesty's reign, and which shall hereafter be surrendered, shall be vested in the king. The knights of St John of Jerusalem were also suppressed by the 32d Henry VIII. c. 24. The suppression of these greater houses by the two acts in question produced a revenue to the king of above L.100,000 a year, besides a large sum in plate and jewels. The last act of dissolution in this king's reign was the act of 37 Henry VIII. c. 4, for dissolving colleges, free chapels, chantries, and the like; which act was further enforced by 1 Edward VI. c. 14. By this act were suppressed ninety colleges, one hundred and ten hospitals, and two thousand three hundred and seventy-four chantries and free chapels.

MONASTIC, something belonging to monks, or the monkish life. The monastic profession is a kind of civil death, which in all worldly matters has the same effect as the natural death. The council of Trent fix sixteen years as the age at which a person may be admitted into the monastic state.

St Anthony was the person who, in the fourth century, first established monastic institutions; as St Pachomius, in the same century, is said to have first set on foot the cœnobitic life, or regular communities of religious. In a short time the deserts of Egypt became inhabited with a set of solitaries, who took upon them the monastic profession. St Basil carried the same spirit into the East, where he composed a rule, which afterwards obtained throughout a great part of the West.

In the eleventh century the monastic discipline had become very remiss. St Odo first began to retrieve it in the monastery of Cluny; that establishment, by the conditions of its erection, was put under the immediate protection of the holy see, with a prohibition to all powers, both secular and ecclesiastical, to disturb the monks in the possession of their effects or the election of their abbot. In virtue of this they pleaded an exemption from the jurisdiction of the bishop, and extended this privilege to all the houses dependent on Cluny. This made the first congregation of several houses, under one chief immediately subject to the pope, so as to constitute one body, or, as it is called, one *religious order*. Till then, each monastery was independent, and subject to the bishop.

MONAVAR, a Spanish town in the province of Valencia, containing 8000 inhabitants; it has a manufacture of linen, and several medicinal baths.

MONDOVI, a province of Piedmont, in the Sardinian dominions. It extends over seven hundred and sixty-two square miles, and comprises four cities, eighty-one towns and villages, and ninety-six rural establishments, with 136,954 inhabitants. Although the Apennines form a part of the southern division of the province, it is on the whole fruitful in corn, wine, hemp, and silk. It has some mines of iron, and several valuable marble quarries. The capital is the city of the same name situated on the river Ellero. It is fortified, is the seat of a bishop, and contains a cathedral, five parish churches, four convents of nuns and eleven of monks, 4000 houses, and 22,570 inhabitants. It is a place of considerable manufacturing industry, making both printed cottons, cloth, silks, and paper. It was the birth-place of the celebrated Beccaria. Long. 7. 45. E. Lat. 44. 23. N.

MONETARIUS, or MONEYER, a name which antiquaries and medallists give to those who struck the ancient coins or moneys. Many of the old Roman coins have the name of the *monetarius*, either written at length, or at least the initial letters of it. See the article MEDALS.

Monastic
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Monetarius.

MONEY.

Money. MONEY¹ is a term used to designate whatever commodity the inhabitants of any particular country, accept either voluntarily or by compulsion, as an equivalent for their labour, and for whatever else they have to dispose of.

SECT. I.—*Circumstances which led to the use of money.*
Principal properties that every commodity used as such ought to possess. Not a sign or a measure of value, but a real equivalent.

Circumstances leading to the use of money.

A country in which the division of labour was unknown, and where every individual or family directly produced the commodities necessary for his or their consumption, would have no exchanges, and consequently no money. But, after the division of labour has been established, the introduction of money becomes necessary, or, at least, highly advantageous. A very small part only of a man's wants is then directly supplied by his own labour. The greater part is indirectly supplied by exchanging that part of the produce of his labour which exceeds his own consumption, for such parts of the produce of other men's labour as he has occasion for, and they are willing to part with. Every man thus lives by exchanging, or becomes in some measure a merchant, and the society itself grows to be what is properly a commercial society.

"But when the division of labour first began to take place, this power of exchanging must frequently have been very much clogged and embarrassed in its operations. One man we shall suppose, has more of a certain commodity than he himself has occasion for, while another has less. The former, consequently, would be glad to dispose of, and the latter to purchase, a part of this superfluity. But, if this latter should chance to have nothing that the former stands in need of, no exchange can be made between them. The butcher has more meat in his shop than he himself can consume, and the brewer and the baker would each be willing to purchase a part of it; but they have nothing to offer in exchange except the different productions of their respective trades, and the butcher is already provided with all the bread and beer which he has immediate occasion for. No exchange can, in this case, be made between them. He cannot be their merchant, nor they his customers; and they are all of them thus mutually less serviceable to one another. To avoid the inconveniency of such situations, every prudent man, in every period of society, after the establishment of the division of labour, must naturally have endeavoured to manage his affairs in such a manner as to have at all times by him, besides the peculiar produce of his own industry, a certain quantity of some one commodity or another, such as he imagined few people would be likely

to refuse in exchange for the produce of their industry." Money. (*Wealth of Nations*, vol. i. p. 43. M'Culloch's ed.)

This commodity, whatever it may be, is money.

An infinite variety of commodities have been used as money in different countries and states of society. Those nations who chiefly subsist by the chase, such as the ancient Russians, and the greater part of the Indians who now occupy the uncultivated portion of America, use the skins of wild animals as money.² In a pastoral state of society cattle are most commonly used for that purpose. Homer tells us, that the armour of Diomedes cost only nine oxen, whilst that of Glaucus cost one hundred. (*Iliad*, lib. 6, lin. 235.) The etymology of the Latin word (*pecunia*), signifying money, and of all its derivatives, proves that cattle (*pecus*) had been the primitive money of the Romans.³ They had also been used as such by the ancient Germans; for their laws uniformly fix the amount of the penalties to be paid for particular offences in cattle. (Storch, *in loco citato*.) In remoter ages corn was very generally used, in agricultural countries, as money; and even now, it is by no means uncommon to stipulate for corn rents and wages. Other commodities have been used in different countries. Salt is said to be the common money of Abyssinia (*Wealth of Nations*, i. p. 45.); a species of shells, called cowries, gathered on the shores of the Maldiv Islands, are used in smaller payments throughout Hindustan, and form the only money of extensive districts in Africa.⁴ Dried fish forms the money of Iceland and Newfoundland;⁵ sugar of some of the West India islands; and Dr. Smith mentions that there was, at the period of the publication of the *Wealth of Nations*, a village in Scotland where it was customary for a workman to carry nails, as money, to the baker's shop or the alehouse. (*Wealth of Nations*, i. p. 45.)

But these commodities are universally deficient in some of the principal requisites which every commodity used as money ought to possess. Products must frequently be brought to market worth only half an ox, or half a skin; but as an ox could not be divided, and as the division of a skin would most probably deprive it of the greater part of its value, it would be impossible to exchange them for such money. Divisibility is not, however, the only indispensable requisite in a commodity used as a medium of exchange. It is necessary that it should admit of being kept for an indefinite period without deteriorating; that it should, by possessing great value in small bulk, be easily transported; and that one piece of money, of a certain denomination, should always be precisely equivalent to every other piece of money of the same denomination. But none of the commodities above named as having been used as money possesses these properties. Though cattle had been sufficiently

Money.

Commodities used as money in different countries.

Defects of these commodities.

¹ Etymologists differ respecting the derivation of the word money. Some contend that it comes from *monere*, (*quia nota inscripta de valore admonet*) because the stamp impressed on coined money indicates its weight and fineness (Bouteroue, *Recherches sur les Monnoyes de France*, p. 1.); and others, that it originates in the circumstance of silver being first coined at Rome in the temple of Juno Moneta. (Suidas, *in voce Μονηται*).

² Storch, *Traité d'Economie Politique*, tome iii. p. 16.; and Ulloa, *Mémoires Philosophiques sur l'Amérique*, tome ii. p. 100.

³ Morellet, *Prospectus d'un Nouveau Dictionnaire de Commerce*, p. 115.

⁴ "Dans les pays où le cuivre a trop de valeur pour pouvoir représenter celle des plus menues denrées, on est encore obligé de lui substituer quelque autre matière plus commune. C'est cette circonstance qui a fait adopter aux Indiens l'usage des *cauris* en guise de petite monnaie. Cet usage pourroit paroître étrange dans les pays aussi riches et d'une civilisation aussi ancienne que le Bengale et l'Indoustan: mais le cuivre y est si rare, et les vivres y sont à si bon marché, qu'une pièce de la valeur de 1 cop. et $\frac{1}{4}$ [about a halfpenny English] peut y acheter une quantité des denrées suffisante pour la subsistence journalière d'un homme du peuple. On est donc obligé de deviser la plus petite monnaie de cuivre en plusieurs fractions; et comme une monnaie d'aussi peu de valeur conteroit plus à fabriquer qu'elle ne pourroit valoir, on la remplace par un coquillage dont la nature fait presque tous les frais. Quelque mince que soit la valeur d'un *cauris*, elle suffit dans ces contrées fertiles pour acheter une pièce des bananes ou quelque autre fruit commun." (Le Goux de Flaix, *Essai sur l'Indoustan*, tom. i. pp. 143—226, quoted by Storch, *Economie Politique*, tom. iii. p. 133.)

⁵ Smith, *ubi supra*; and Horrebow, *Description de l'Islande*, tome ii. p. 90.

Money. divisible, they could neither be preserved, nor transported from one place to another, without a great deal of trouble and expence; while, owing to the difference in their qualities, one ox might be worth two or three oxen of an inferior species. It is plain, therefore, that they could not serve as money except in a very rude state of society, when the arts were almost unknown, and when the rearing of cattle formed the principal employment. Corn was sufficiently divisible; but its bulk was far too great in proportion to its value to admit of its easy transportation, and it also was of very different and not easily appreciated qualities. Salt, sugar, shells, and fish, are all liable to insuperable objections. The values of equal quantities of all of them differ very greatly; some of them cannot be divided, and others cannot be preserved or transported without great loss.

But the commodities in question were deficient in a still more important particular. Their value was not sufficiently *invariable* to permit of their being advantageously used as money. They were not durable commodities, nor was it possible to adjust their supply so as to avoid sudden fluctuations of price. The occasional abundance and scarcity of pasture has a powerful influence on the price of cattle, which is still more seriously affected by the prevalence of epidemical diseases, and other contingencies. The fluctuations in the price of corn, arising from the variations of the seasons, are too striking and obvious to require to be pointed out. And in the islands where cowries are picked up, a strong gale from a particular point of the compass has frequently, in a few hours, sunk their value considerably. It was impossible, therefore, that such commodities could ever be either generally or permanently used as money in civilized societies. No person would willingly exchange the produce of his industry for a commodity which might, in a few weeks, or even days, lose a third, or a half, of its value.

Gold and silver the fittest materials for money;

The desire of uniting the different qualities of invariability of value, divisibility, durability, facility of transportation, and perfect sameness, doubtless formed the irresistible reasons which have induced mankind, in every civilized society, to employ gold and silver as money. The value of these metals is certainly not invariable, but it changes only by *slow* degrees; they are divisible into any number of parts, and have the singular property of being easily reunited, by means of fusion, without loss; they do not deteriorate by being kept; and, from their firm and compact texture, they are very difficult to wear; their cost of production, especially of gold, is so considerable, that they possess great value in small bulk, and can, of course, be transported with comparative facility; and an ounce of pure gold and silver, taken from the mines in one quarter of the world, is precisely identical with an ounce of pure gold or silver dug from the mines in any other quarter. No wonder, therefore, when almost all the qualities necessary to constitute money are possessed in so eminent a degree by the precious metals, that they have been used as such, in civilized societies, from a very remote era. They became *universal* money, as M. Turgot has observed, "not in consequence of any arbitrary agreement among men, or of the intervention of any law, but by the nature and force of things."

first used as money in the shape of bars or ingots.

A considerable period must, however, have elapsed after the introduction of the precious metals into commerce, before they were generally used as money. But, by degrees, the various qualities, which so peculiarly fit them for this purpose, would become obvious; and every individual, in consulting his own advantage, would endeavour to exchange a part, at least, of the produce of his industry for commodities which could be easily concealed or carried about, which

did not deteriorate by being kept, and of which he could give a portion equal in value to the value of any other commodity he might afterwards wish to obtain. When first brought to market, gold and silver, like copper, iron, or any other metal, were in an unfashioned state, in bars or ingots. A sheep, an ox, a bushel of wheat, &c. was then bartered for a piece of gold or silver, exactly as it would have been bartered for iron, copper, cloth, or any other commodity. The parties first agreed upon the *quality* of the metal to be given for the goods, and the *quantity*, which the possessor of the metal had bound himself to pay, was next ascertained by weight. Nor is this a mere conjectural statement, advanced in a later age to explain appearances, and resting on probability only. Aristotle (*Polit.* lib. i. cap. 9.) and Pliny (*Hist. Nat.* lib. 33, cap. 3.) tells us, that such was, in fact, the original method by which the precious metals were exchanged in Greece and Italy; and the sacred writings present us with a striking and remarkable example of the prevalence of the same primitive practice in the East. We are there told that Abraham *weighed* four hundred shekels of silver, and gave them in exchange for a piece of ground he had purchased from the sons of Heth, (*Genesis*, chap. xxiii. ver. 16.) It is also mentioned, that this silver was "*current money with the merchant*," an expression which evidently refers to its quality only. For, had it been coined, or marked with a stamp, indicating its weight and fineness, it would have been unnecessary to have weighed it. These ancient practices still subsist in various countries. In many parts of China, gold and silver do not circulate as coin under the authority of a public stamp, but their value is always ascertained by weight. When exchanged, they are cut into pieces, supposed to be nearly proportioned to the value of the commodity they are to be given for; and the pieces are then weighed to ascertain their precise value. This practice is also prevalent in Abyssinia and Tonquin.¹

Before the art of metallurgy was well understood, the baser metals were frequently used as money. Iron was the pimitive money of the Lacedemonians, and copper of the Romans. But both iron and copper deteriorate by being kept; and, besides this defect, the rapid improvement of the arts, and the consequent reduction of their price, speedily rendered their bulk in proportion to their value too great to permit of their continuing to be used as money. Copper, however, is still advantageously used in the form of tokens, convertible into silver in very small payments. In Great Britain, copper pence and halfpence are at present rated at about seventy-two per cent. above their real value; but as the issue of them is exclusively in the hands of government, and as they are legal tender to the extent of one shilling only, in any one payment, this over-valuation has not, for reasons which we shall afterwards explain, had any bad effect.²

The trouble and inconvenience attending the weighing of the quantity of metal in every exchange of gold and silver for commodities must have been early experienced. But the greatest obstacle to the use of unfashioned metals as money, would undoubtedly be found in the difficulty of determining their quality, or the degree of their purity, with sufficient facility and accuracy. The operation of *assaying*, is one of great nicety and delicacy; and, notwithstanding all the assistance derived from modern art, it is still no easy matter to ascertain the precise degree of purity of a particular piece of metal. In early ages, such an operation must have been performed in a very clumsy and bungling manner. It is most probable, indeed, that when the precious metals were first used as money, their quality was appreciated only by their weight and colour. A very short ex-

¹ Goguet, *De l'Origine des Loix*, &c. tom. i. p. 268, 4to edit. See also Park's *Travels*, vol. i. p. 464, 8vo edit.

² See *Memorandum on the Silver Coinage of 1817*, by the Master of the Mint, p. 378 of the Appendix to the Lord's Report on the Resumption of Cash Payments by the Bank.

Money. perience would, however, be sufficient to show the extreme inexactness of conclusions derived from such loose and unsatisfactory criteria; and the devising of some method by which the fineness of the metal might be easily and correctly ascertained, would very soon be felt as indispensable to the general use of gold and silver as money. Such a method was not long in presenting itself. It was early discovered, that, to ascertain the purity of the metal, and also to avoid the trouble and expense of weighing it, no more was necessary than to mark each piece with a *stamp*, declaring its weight and fineness. Such seem to have been the various steps which led the ancients to the introduction of *coined money* (Goguet, *De l'Origine des Loix*, &c. tom. i. p. 269,); an invention of the very greatest utility, and which has, perhaps, contributed more than any other, to facilitate commerce, and to accelerate the progress of civilization and the arts.

Advantages of coined money. "Without some article of known exchangeable value, such as coin, readily received as an equivalent for other things, the interchange of commodities must have been very limited, and consequently the divisions of labour very imperfectly established. Now, money obviates these evils, and by a twofold operation, augments production. In the first place, it saves all that time and labour which, while the intercourse between man and man is carried on by barter, must frequently intervene before a person can be supplied with the quantity of the commodity which he wants. In the second place, and in consequence of its saving the time and labour which must otherwise be spent in effecting exchanges, it multiplies the transactions of mercantile industry, and thus allows the divisions of employment to be more thoroughly established. By the first operation, it disengages a very considerable portion of labour from an unproductive occupation, and enables it to receive a more useful direction. By the second operation, it increases in a very high degree the productive powers of the labour already usefully employed. It assists every man in availing himself of the skill and dexterity which he may have acquired in any particular calling, and promotes cultivation in a manner suitable to the climate and soil of different districts, and of different countries. And by both these operations, coined money increases to an extent, not easy to be calculated, the wealth of civilized communities." (Torrens on the Production of Wealth, p. 305.)

Coined money not a sign, or a measure of value. But, whatever may be the advantages attending the use of coined money, and they are great and obvious, it is necessary to observe, that its introduction does not affect the nature of exchanges. Equivalents are still given for equivalents. The exchange of a quarter of corn for an ounce of pure unfashioned gold bullion, is undeniably as much a real barter, as if it had been exchanged for an ox, or a barrel of beer. But supposing the metal to have been formed into a coin, that is, marked with a stamp indicating its weight and fineness, it is plain that circumstance could have made no change in the terms of the barter. The coinage saves the trouble of weighing and assaying the bullion, but it does nothing more. A coin is merely a piece of metal of a known weight and fineness; and the commodities exchanged for it are always held to be of equal value. And yet these obvious considerations have been very generally overlooked. Coined money, instead of being viewed in the same light as other commodities, has been looked upon as something quite mysterious. It was said to be both a *sign* and a *measure* of value. In truth, however, it is neither the one nor the other. A sovereign is not a sign, it is the thing signified. A promissory note, payable at some stated period, may not improperly be considered as the sign of the specie to be paid for it; but that specie is itself a commodity possessed of real exchangeable worth. It is equally incorrect to call money a measure of value. Gold and silver do not measure the value of commodities, more than the latter measure the

value of gold and silver. Every thing possessed of value may either measure, or be measured by, every thing else possessed of value. When one commodity is exchanged for another, each measures the value of the other. If the quartern loaf were sold for a shilling, it would be quite as correct to say, that a quartern loaf measured the value of a shilling, as that a shilling measured the value of a quartern loaf.

The quality of serving as a measure of value is, therefore, equally inherent in every commodity. But the slow degrees by which the precious metals change their value, renders them peculiarly well fitted for forming a standard, by which to compare the values of other and more variable commodities. To this standard reference is almost always made in estimating the value of the products of every civilized country. We do not say, that one man is worth a thousand acres of land, and that another is worth a thousand sheep; but we ascertain for how much gold or silver the land and the sheep would exchange, and then say, that their proprietors are worth so much money. In this, however, there is certainly nothing mysterious. We merely compare the value of one commodity with the value of another; and as coin or money has been found to be the most convenient standard of comparison, the value of all other commodities is usually estimated in it.

It is obvious, from this statement, that the terms of the exchange of one commodity, or set of commodities, for another, may be adjusted, with reference to money, without any money being actually in the possession of either of the parties making the exchange. If a horse, for example, had commonly sold for ten pieces of silver, an ox for five pieces, and a sheep for one piece, it would mark their relative values to each other, and the animals might be exchanged on this footing without the intervention of money. The frequent recurrence of transactions of this kind seems to have given rise to the notion of an abstract or ideal standard of value. Thus, instead of saying that a horse is worth ten pieces of silver, an ox five pieces, and a sheep one piece, it has been contended that it might equally have been said that they were respectively worth ten points or units, five points or units, and one point or unit; and that, as the proportional values of commodities might be as clearly expressed in these arbitrary terms as in money, or any commodity possessed of real value, the use of the latter, as a standard, might be advantageously dispensed with, and a set of abstract terms adopted in its stead. This, however, is completely mistaking the nature and object of a standard. A standard is not intended to mark the known relations between different commodities, but to enable us easily to discover those which are unknown. Now, although the series of arbitrary terms may serve extremely well for the first of these purposes, it is utterly impossible that they can ever serve for the second. This, however, is exclusively the object of a standard; and it is quite plain that nothing can be used as such which is not possessed of the same properties as the things with which it is to be compared. To measure length, a standard must have length; to measure value, it must have value. The value of commodities is ascertained by separately comparing their cost with the cost of money, and we express their relation to each other by simply stating the result of our inquiries; that is, by mentioning the number of livres, of pounds, or of fractions of a pound, they are respectively worth. And, when any new commodity is offered for sale, or when any change is made in the cost of an old one, we ascertain their relation to the rest, by merely comparing them with a livre or a pound. It is plainly impossible, however, that we could have done this, had the terms livre, or pound, been purely arbitrary, and referable to no really valuable article. We might as well try to estimate distances by an imaginary inch, or an imaginary foot, as to estimate prices or values by an imaginary shilling, or an imaginary sovereign. When we say

Money. Use of gold and silver as a standard for estimating the relative value of commodities.

Proof of the non-existence of an abstract or ideal standard.

Money. that an ox is worth five pounds, and a sheep only one, we really mean no more than that, when an ox and a sheep are compared together, that is, when the one serves as a standard by which to estimate the value of the other, one ox is found to be worth five sheep. But, suppose that we wish to ascertain what is the relative value of some other commodity; of a pound of tea, for example; to oxen or sheep, of what use would it be to be told that one ox was worth five sheep, or that, when the value of an ox was represented by the imaginary term "five pounds," the value of a sheep was represented by the imaginary term "one pound?" It is not the relation between oxen and sheep, but the relation between these animals and tea, that we are desirous of learning. And, although this relation may be learned by comparing the cost of producing oxen and sheep with the cost of producing tea, or by ascertaining for how much of some other commodity an ox, a sheep, and a pound of tea, will respectively exchange, it is obvious it could never be learned by comparing them with a set of arbitrary terms or symbols! It would not, in truth, be more absurd to attempt to ascertain it by comparing them with the hieroglyphics on an Egyptian sarcophagus. Nothing that will not exchange for something else, can ever be a standard, or measure of value. Commodities are always compared with commodities and not with abstract terms. Men go to market with real values, and not with the signs of values in their pockets. And it is to something possessed of real worth, to the gold contained in a sovereign and not in the word sovereign, that they always have referred, and must continue to refer, in estimating value.¹

In common mercantile language, the giving of money for a commodity is termed *buying*, and the giving of a commodity for money, *selling*. *Price*, unless when the contrary is particularly mentioned, always means the value of a commodity rated in money.

Having thus endeavoured to explain the circumstances which led to the introduction of money, and to shew what it really is, and what it is not, we shall now proceed to investigate the laws by which its value is regulated. It is chiefly from the prevalence of erroneous opinions on this subject, that the theory of money has been so much misunderstood.

¹ The following passage of Montesquieu has often been referred to in proof of the existence of an ideal standard:—"Les noirs de la côte d'Afrique ont un signe des valeurs sans monnaie; c'est un signe purement idéal fondé sur le degré d'estime qu'ils mettent dans leur esprit à chaque marchandise, à proportion du besoin qu'ils en ont; une certaine denrée, ou marchandise, vaut trois macutes; une autre, six macutes; une autre, dix macutes; c'est comme s'ils disoient simplement trois, six, dix. Le prix se forme par la comparaison qu'ils font de toutes les marchandises entre elles: pour lors, il n'y a point de monnaie particulière, mais chaque portion de marchandise est monnaie de l'autre." (*Esprit des Loix*, livre xxii. cap. 8.)

But, instead of giving any support to the notion of an abstract standard, this passage might be confidently referred to in proof of its non-existence. Had Montesquieu said that the blacks determined the values, or prices, of commodities, by comparing them with the arbitrary term *macute*, the statement, though false, would have been at least in point. But he says no such thing. On the contrary, he states distinctly, that the relative values of commodities (marchandises) are ascertained by comparing them *with each other* (entre elles), and that it is merely the result of the comparison that is expressed in arbitrary terms.

So much for the weight to be attached to this statement, supposing it to be well-founded. The truth is, however, that the term *macute* is not really arbitrary, and employed only to mark an ascertained proportion, but that it has a reference to, and is, in fact, *the name of an intrinsically valuable commodity*. "On a bien dit," says l'Abbé Morellet, "que ce mot *macute* étoit une expression abstraite et générale de la valeur, et cela est vrai au sens où nous l'expliquerons plus bas; mais on n'a pas remarqué que cette abstraction a été conséquente et postérieure à l'emploi du mot *macute* pour signifier une *marchandise*, une *denrée réelle* à laquelle on avoit longtems comparé toutes les autres."

"Macute en plusieurs lieux de la côte d'Afrique, est encore le nom d'une certaine étoffe: 'Chez les negres de la côte d'Angola,' dit le voyageur Angelo, 'les *macutes* sont des pièces de nattes d'une aune de long; Jobson dit aussi que les *macutes* sont une espèce d'étoffe.'

"Les étoffes ont toujours été l'objet d'un besoin très-pressant chez des peuples aussi barbares, dépourvus de toute espèce d'industrie.—Les nattes en particulier leur sont de la plus grande nécessité. Elles sont divisées en morceaux peu considérables et d'une petite valeur; elles sont très-uniformes dans leurs parties, et les premières qu'on a faites auroient pu être semblables les unes aux autres, et d'une bonté égale, sous la même dénomination; toutes ces qualités les ont rendu propres à devenir la mesure commune des valeurs."—(*Prospectus d'un Nouveau Dictionnaire de Commerce*, p. 121.)

The following extract from Park's *Travels* gives an example of a similar kind: "In the early intercourse of the Mandingoes with the Europeans, the article that attracted most notice was iron. Its utility in forming the instruments of war and husbandry made it preferable to all others; and iron soon became the measure (standard) by which the value of all other commodities was ascertained. Thus a certain quantity of goods, of whatever denomination, appearing to be equal to a bar of iron, constituted, in the trader's phraseology, a bar of that particular merchandise. Twenty leaves of tobacco, for instance, were considered as a bar of tobacco; and a gallon of spirits (or rather half spirits and half water) as a bar of rum; a bar of one commodity being reckoned equal in value to a bar of another commodity. As, however, it must unavoidably happen, that, according to the plenty or scarcity of goods at market, in proportion to the demand, the relative value would be subject to continual fluctuation, greater precision has been found necessary; and, at this time, the current value of a single bar of any kind is fixed by the whites at *two shillings sterling*. Thus, a slave, whose price is £15, is said to be worth 150 bars." (*Travels in the Interior of Africa*, 8vo edit. vol. i. p. 39.)

SECT. II.—Circumstances which Regulate the Exchangeable Value of Money.

This branch of our subject naturally divides itself into two parts: 1st, an inquiry into the principles which regulate the exchangeable value of money when the power to supply is not monopolised; and, 2d, an inquiry how far these principles are liable to be affected by the operation of monopoly.

I. There does not now seem to be much room for difference of opinion respecting the circumstances that regulate the value of the precious metals, and their distribution throughout the various countries of the globe. Bullion is a commodity, on the production of which competition operates without restraint. It is not subjected to any species of monopoly, and its value in exchange must, therefore, be entirely regulated by the cost of its production, that is, by the quantity of labour required to bring a given quantity of it to market.

If, in every stage of society, it required precisely the same quantity of labour to produce a given quantity of bullion, its value would be *invariable*; and it would constitute a standard by which the variations in the exchangeable value of all other commodities could be *correctly* ascertained. But this is not the case either with bullion or any thing else. And its value fluctuates in the same way as that of other commodities, not only according to the greater or less productiveness of the mines from which it is extracted, but also according to the comparative skill of the miners, and the improvements of machinery.

M. Say has, in his work on *Political Economy*, a chapter "De la valeur que la qualité d'être monnaie ajouté à une marchandise." But a little reflection will convince us, that M. Say is mistaken, and that the circumstance of the precious metals being used as money cannot affect their value. M. Say reasons on the common hypothesis, that an increase of demand is always productive of an increase of value, an assumption totally at variance with principle and fact. Value depends upon the cost of production; and it is obvious that the cost of producing a commodity may be diminished, whilst the demand for it is increasing. This is so plain a proposition, as hardly to require to be substantiated by argument.

Money.

Cost of production regulates the value of money, when the power of supply is not monopolised.

Money. And a reference to the case of cotton goods, the price of which has, notwithstanding the vast increase of demand, been constantly on the decline during the last half century, is enough to convince the most sceptical of the extreme erroneousness of M. Say's conclusion. But, with regard to the particular case of the precious metals, it is clear the capital devoted to the production of gold and silver must yield the common and ordinary rate of profit; for, if it yielded more than that rate, there would be an influx of capital to the mining business; and, if it yielded less, it would be withdrawn, and vested in some more lucrative employment. And hence, though the demand for gold and silver should, from the adoption of some other commodity as an instrument of exchange, gradually become less, the value of the precious metals would not, on that account, be reduced. A smaller supply would, indeed, be annually brought to market, and a portion of the capital formerly engaged in the mining, refining, and preparing of the metals, would be disengaged; but as the whole stock thus employed yielded only the average rate of profit, the portion which is not withdrawn must continue to do so; or, which is the same thing, gold and silver must still continue to sell for the same price. It is no doubt true, that where mines are, as they almost always are, of different degrees of productiveness, any great falling off in the demand for bullion might, by rendering it unnecessary to work the inferior mines, enable the proprietors of the richer mines to continue their work, and to obtain the ordinary rate of profit on their capitals, by selling bullion at a reduced price. In this case the value of bullion would be really diminished; but it would be diminished, not because there was a falling off in the demand, but because there was a *greater facility of production*. On the other hand, an increased demand for bullion, whether it arose from the general suppression of paper money, or from a greater consumption of gold and silver in the arts, or from any other cause, would not, unless it were necessary, in order to procure the increased supply, to have recourse to less productive mines, be accompanied by any rise of price. If the mines from which the additional supplies were drawn were less productive than those already wrought, more labour would be necessary to procure the same quantity of bullion, and, of course, its price would rise. But, if no such increase of labour was required, its price would remain stationary, though a thousand times the quantity formerly required should be demanded.

After gold and silver have been brought to market, their conversion into coin or manufactured articles, depends entirely on a comparison of the profits that may be derived from each operation. No bullion would be taken to the mint if it would yield a greater profit by sending it to a silversmith; and no silversmith would work up bullion into plate, if he could turn it to greater account by converting it into coin. The value of bullion and coin must, therefore, in countries where the expenses of coinage are defrayed by the state, nearly correspond. When there is any unusual demand for bullion in the arts, coin is melted down; and when, on the contrary, there is any unusual demand for coin, plate is sent to the mint, and the equilibrium of value maintained by its fusion.

It appears, therefore, that whilst competition operates without restraint on the production of gold and silver, they are, like all other things, produced under similar circumstances, valuable only in proportion to the cost of their production; that is, in proportion to the quantity of labour necessarily expended in bringing them to market. And hence, while they constitute the currency of the commercial world, the price of commodities, or their value compared with gold or silver, will vary, not only according to the variations in the exchangeable value of the commodities themselves, but also according to the variations in the value of the gold or silver with which they are compared.

II. But if competition were not allowed to operate on the production of the precious metals, if they could be monopolised and limited in their quantity, their exchangeable value would no longer be regulated by the same principles. If, after the limitation, they still continued to be used as money, and if, in consequence of the improvement of society, manufactured commodities and valuable products should be very much multiplied, the exchanges which this *limited* amount of money would have to perform would be proportionably increased; and, of course, a proportionably smaller sum would be appropriated to each particular transaction; or, which is the same thing, money prices would be diminished. Whenever the supply of money is *fixed*, the amount of it, given in exchange for commodities, must *vary inversely as the demand, and can be affected by nothing else*. If double the usual supply of commodities be brought to market in a country with a limited currency, their money price will be reduced a half; and if only half the usual supply be brought to market, it will be doubled; and this, whether the cost of their production be increased or diminished. Produce is not then exchanged for money, on the ground that it is a commodity capable of being advantageously used in the arts, or that an equal quantity of labour has been expended on its production; but because it is the universal equivalent used by the society, and that, as such, it will be willingly received for the produce belonging to others. The remark of Anacharsis, the Scythian, that gold and silver coins seemed to be of no use but to assist in numeration and arithmetic, (Hume's *Essay on Money*), would, if confined to a strictly *limited currency*, be as just as it is ingenious. Sovereigns, livres, dollars, &c., would then really constitute mere tickets or counters, for computing the value of property, and transferring it from one individual to another. And as small tickets or counters, would serve for this purpose quite as well as large ones, it is unquestionably true, that a debased currency may, by first reducing, and then limiting its quantity, be made to circulate at the value it would bear if the power to supply it were unrestricted, and if it were possessed of the legal weight and fineness; and, by still further limiting its quantity, it might be made to pass at any higher value.

Thus it appears, that whatever may be the *material* of the money of any country, whether it consist of gold, silver, copper, iron, leather, salt, cowries, or paper, and however destitute it may be of all *intrinsic* value, it is yet possible, by *sufficiently limiting its quantity*, to raise its value in exchange to any conceivable extent.

Suppose the money of Great Britain consists of 50,000,000 or 60,000,000 of one pound notes, and that we are prevented from increasing or diminishing this sum, either by issuing additional notes or coins, or by withdrawing the notes already in circulation; it is obvious that the quantity of commodities for which such notes would exchange, would increase or diminish precisely according to the increase or diminution of the commodities brought to market. If we suppose that ten times the amount of products that were offered for sale when the limitation of the currency took place, are offered for sale ten or twenty years afterwards, and that the rapidity of circulation has continued the same, prices will have fallen to *one-tenth* of their former amount; or, which is the same thing, the exchangeable value of the paper money will have increased in a tenfold proportion; and, on the other hand, if the products brought to market had diminished in the same proportion, the exchangeable value of the paper money will have been equally reduced.

The principles we have now stated are of the utmost importance to a right understanding of the real nature of money. Previously to the publication of Mr. Ricardo's *Principles of Political Economy*, every writer of authority maintained, that the value of money depended entirely on the relation between its amount and the demand. But this is

Money. The proportion between the supply and demand regulates the value of money, when the power of supply is monopolized.

Money. true only of a gold or silver currency when its quantity is *limited*, and of a currency formed of materials having little intrinsic worth, as paper, when its quantity is *limited*, and it is not made convertible, at the pleasure of the holder, into some more valuable commodity, the production of which is under no restraint. It is obvious, indeed, without any reasoning on the subject, that the value of a currency that costs little or nothing, can only depend on the proportion which its amount bears to the commodities brought to market, or to the business it has to perform. And wherever a currency of this kind, or a limited gold currency, is in circulation, the common opinion, that the prices of commodities are regulated exclusively by the proportion between the quantity of them brought to market, and the supply of money, and that any considerable increase or diminution of either will proportionally affect prices, is quite correct. It is altogether different, however, with a currency consisting of gold or silver, or of any other commodity possessed of considerable value, and the supply of which may be increased to an unlimited extent by the operation of unrestricted competition.

The fluctuations in the supply of, and demand for, such money, have no permanent effect on its exchangeable value; this depends exclusively on the comparative *cost of its production*. If a sovereign commonly exchanges for a couple of bushels of wheat, or a hat, it is because the same labour is required for its production as for that of either of these commodities; while, if with a limited and inconvertible paper money, they exchange for a one pound note, it would be because such was the proportion which, as *a part of the mass of commodities offered for sale, they bore to the supply of paper or money in the market*. This proportion would, it is evident, be not only immediately, but permanently, affected by an increase or diminution either of paper or commodities. But the relation which commodities bear to a freely supplied metallic currency, could not be permanently changed, except by a change in the cost of producing the commodities or the metals.

Our readers must not conceive from what is now stated, that we mean to contend that the value of gold or silver is never affected by variations of supply and demand. Such an opinion would be altogether erroneous. At the same time it must be admitted, that their value is much less affected by such variations, than that of almost any other commodity. Their great durability precludes the possibility of any sudden diminution of their quantity, while the immense surface over which they are spread, and the various purposes to which they are applied, prevent any unusual productiveness of the mines from speedily lowering their value. An extraordinary event, such as the discovery of America, or the establishment of an intercourse between a country where bullion bore a high value, and one where its value, from the greater facility of its production, was comparatively low, would, by causing a sudden exportation and importation, raise its value in the one country, and sink it in the other. But such events must necessarily be of very rare occurrence. And although the different productiveness of the mines, to which, in the progress of society, recourse must be had, and the successive improvements in the art of mining and working metals, must render the value of gold and silver very different at distant periods, it is abundantly uniform to secure us against all risk of sudden and injurious fluctuations.

Such are the circumstances which regulate the value of money; first, when the power to supply it is not subjected to any species of monopoly; and, second, when it is monopolised and limited. In the former case, its value depends,

like that of all other commodities, on the cost of its production; while, in the latter case, its value is totally unaffected by that circumstance, and depends entirely on the extent to which it has been issued, compared with the demand.

The conclusions deducible from the fundamental principle we have thus endeavoured to establish, are of the utmost importance. A metallic currency, on the coinage of which a high seignorage or duty was charged, and a paper currency not convertible into the precious metals, were occasionally seen to circulate at the same value with a metallic currency of full weight, and which had been coined at the expence of the state. But no rational or consistent explanation of these apparently anomalous results could be given until the effects produced by limiting the supply of money had been accurately appreciated. Now, however, that this has been done, all these difficulties have disappeared. The theory of money has been perfected, and we are enabled to shew what, under any given circumstances, would be the effect of imposing a seignorage, or of issuing an inconvertible paper currency.

SECT. III.—*A moderate Seignorage on Coined Money shewn to be advantageous. Principles which should regulate its amount.*¹

The government of almost every country has retained the power of coining exclusively in its own hands. In antiquity this privilege was reserved merely to prevent the confusion that must attend the circulation of coins of different denominations were individuals permitted to issue them at pleasure, and to give the public greater security, that the stamp should truly indicate the weight and fineness of the metal.² But in more modern times it has been used not only as a means of affording a better guarantee to the public, but also of increasing the revenues of the state. As to the expediency of this, however, much difference of opinion has existed. It has been contended that the state ought in no circumstances to charge any duty on coined money; and that the expences of the mint should always be defrayed by the public. In this opinion we cannot concur; and it appears to us that the reasoning of Dr. Smith, in favour of a moderate seignorage, is quite unanswerable. No good reason has yet been given why those who want coins should not have to pay the expences of manufacturing them. Coinage, by saving the trouble and expence attending the weighing and assaying of bullion, indisputably adds to the value of the precious metals. It renders them fitter to perform the functions of a circulating medium. A sovereign is of greater value than a piece of pure unfashioned gold bullion of the same weight; and for this plain reason, that while it is equally well adapted with the bullion for being used in the arts, it is better adapted for being used as money, or in the exchange of commodities. Why then should government be prevented from charging a seignorage, or duty on coins, equal to the expences of the coinage, or, which is the same thing, to the value which it adds to the bullion? Those who contend that the state ought to defray the expence of the coinage, might, with equal cogency of reasoning, contend that it ought to defray the expence of manufacturing gold and silver tea-pots, vases, &c. In both cases the value of the raw material, or bullion, is increased by the cost of workmanship. And it is only fair and reasonable, that those who carry bullion to the mint as well as those who carry it to the jewellers, should have to pay the expences necessarily attending its conversion into coin.

But there are other reasons why a seignorage, to this extent at least, ought to be exacted. Wherever the expences

Money.

Reasons why a seignorage should be imposed on coined money.

¹ Seignorage, strictly speaking, means only the clear revenue derived by the state from the coinage; but it is now commonly used to express every deduction made from the bullion brought to the mint to be coined, whether on account of duty to the state, or of the expence of coinage (properly *brassage*). We always use the phrase in its more enlarged sense.

² Le Blanc, *Traité Historique des Monnoyes de France*, p. 90, ed. Amst. 1692.

Money. of coinage are defrayed by the state, an ounce of coined gold or silver, and an ounce of gold or silver bullion, must be very nearly of the same value. And, hence, whenever it becomes profitable to export the precious metals, coins, in the manufacture of which a considerable expence has been incurred, are sent abroad indifferently with bullion. It has indeed been attempted, by prohibiting the exportation of coins, to prevent the loss that may thus be occasioned; but these efforts have proved singularly ineffectual, and have, indeed, been abandoned in this and most other countries. Admitting, however, that it were possible, which most certainly it is not, to prevent, or at least, materially limit, the clandestine exportation of coins, it is conceded on all hands to be quite nugatory to attempt to prevent their conversion into bullion. In this there is almost no risk. And the security with which their fusion can be effected, and the trifling expences attending it, will always enable them to be melted down and sent abroad whenever there is any unusual foreign demand for the precious metals. This exportation would, however, be either prevented or materially diminished by the imposition of a seignorage or duty, equal to the expence of the coinage. The coins being, by this means, rendered more valuable than bullion, would be kept at home in preference: and if, as Dr. Smith has observed, it became necessary on any emergency to export coins, they would, most likely, be re-imported. Abroad they would be only worth so much bullion, while at home they would be worth this much, and the expence of coinage besides. There would, therefore, be an obvious inducement to bring them back, and the supply of currency would be maintained at its proper level, without its being necessary for the mint to issue fresh coins.

Besides relieving the country from the useless expences attending the coinage of the money exported to other countries as an article of commerce, the imposition of a moderate seignorage would either totally prevent, or at least lessen that fusion of the heavier coins, which always takes place whenever a currency becomes degraded or deficient in weight. Previously to the great recoinage in 1773, the quantity of bullion contained in the greater number of the gold coins in circulation was reduced nearly two per cent. below the mint standard; and, of course, the price of gold bullion, estimated in this degraded currency, rose two per cent., or from £3, 17s. and 10½d., its mint price, to £4. This, however, was too minute a difference to be taken into account in the ordinary business of buying and selling. And the possessors of coins fresh from the mint, or of full weight, not obtaining more produce in exchange for them than for the lighter coins, sent the former to the melting pot, and then sold them as bullion. But it is easy to see that this fusion would have been effectually prevented had the coins been loaded with a seignorage of two per cent. The heavy coins could not then have been melted without losing the value given them by the seignorage; and this being equal to the excess of the market price of bullion above the mint price, nothing would have been gained by the melters. Had the seignorage been less than the average degradation of the coin, or two per cent.; had it, for example, been only one per cent. all those coins whose value was not more than one per cent. degraded below their mint standard, might have been melted; but if the seignorage had exceeded two per cent. no coins whatever could have been melted until the degradation had increased to the same or a greater extent.

This reasoning proceeds throughout on the supposition that the coins on which the seignorage is charged are not issued in excess. If they were, the above mentioned consequences would not follow. Their too great multiplication might sink them even below their value as bullion, and occasion their immediate fusion or exportation. So long, however, as the state only coins the bullion brought to the mint by indivi-

duals, there is no risk of this happening. No one, we may depend upon it, will ever carry bullion to that establishment, and pay the expences of its coinage, unless the coins be thereby rendered so much more valuable than the unfashioned metal.

Should the government choose to buy bullion, and coin money on its own account, it might, by a little attention, easily avoid all over-issue. Suppose the seignorage were two per cent., then any given weight of coins of the mint standard ought, provided the currency be not redundant, to purchase two per cent. more than the same weight of bullion. So long, therefore, as this proportion is preserved between coined money and bullion, it shews that the proper supply of currency has been issued. If the value of the coins decline below this limit, too many of them must have got into circulation; and, if, on the contrary, their value increase, the supply is too limited, and an additional quantity may be advantageously issued.

It is easily seen, from the principles already established, that it is not necessary that the charge for seignorage should be limited to the mere expences of coinage. It may, without injury to any individual, be carried considerably farther. Provided the amount of the coins on which a seignorage is imposed, be limited to the amount that previously circulated in the country, its imposition, to whatever height it might be carried, would not affect their exchangeable value. The state having the exclusive privilege of coining, no additional supply of money could be brought to market. And supposing the business of the society to continue the same; that is, supposing the same quantity of commodities are brought to market, and exchanged for the same amount of coins of the same denomination, it is clear prices could not be in any way affected. Invariability of value is the great desideratum in money; and provided this be maintained, as it always may be, by properly limiting the quantity in circulation, it is of no consequence whether the weight of the coins be increased or diminished. A hat that had previously to the imposition of the seignorage sold for a sovereign would still fetch one. The sovereign, it is true, has been diminished in size; but as its value is increased in proportion to this diminution, and as small coins are equally well adapted to serve every purpose of a circulating medium as those that are larger, the society would not suffer any inconvenience from that circumstance. It is certain, indeed, that if the monopoly were not rigorously enforced, or if individuals were permitted to issue supplies of money from private mints, free from the charge of seignorage, the increase of quantity would speedily sink the value of the whole coins in circulation to a level with the cost of those produced on the lowest terms; so that the coins on which a high seignorage had been charged, would not be more valuable than those exempted from that charge. But, wherever the supply of money is limited, and competition excluded, this principle ceases to operate, and its value is then dependent upon the proportion which the total quantity in circulation bears to the total demand. This principle is farther elucidated in a very able article on seignorage, by Mr. Tooke, printed in the *Appendix* (p. 180) *To the Lords' Report of 1819*.

It must not, however, be concealed, that if it were attempted to charge a very high seignorage, it would be extremely difficult to limit the supply of coins. The inducement to counterfeit money would, under such circumstances, be very greatly increased, while the chances of detection would be very much diminished. It would not then be necessary, in order to derive a profit from counterfeit coins, that they should be manufactured of a baser metal. The saving of a heavy charge on account of seignorage might of itself afford a sufficient profit; and this could be derived, though the metal contained in the forged coins were of the standard purity. But, though it might, for this reason, and most probably would, be quite impossible to

Money.

If the supply of coins could be sufficiently limited, a high seignorage might be exacted.

Difficulty of limiting sufficiently the supply of coins, and necessity of imposing only a moderate seignorage.

Money. limit the supply of currency, and consequently to sustain its value, were an exorbitant seignorage charged, the same difficulty would not stand in the way of a moderate one. The nefarious business of counterfeiting could not be carried on did it not yield a sufficient premium to the forgers to indemnify them for the risks and odium to which they are exposed. A seignorage less than this would be no encouragement to the issue of counterfeit coins. And though it might be difficult to form any very precise estimate of what this premium might be, it is pretty certain it would not be under from four to five per cent.

Amount of the gold coinage since the accession of James II.

It appears from an account inserted in the appendix to the Report drawn up by the Lords in 1819, that new gold coins, of the value of £74,501,586, had been issued by the mint between the 1st January 1760, and the 13th April 1819. To this sum we have to add nearly fifty millions since issued, making in all an issue of about one hundred and twenty-four or one hundred and twenty-five millions of gold coins since the accession of George III. But the seignorage was remitted in the reign of Charles II.; and it appears from the accounts published by Mr. Ruding and others that £28,172,149 of new gold coins were issued in the period between the accession of James II. (1685) and the demise of George II.; so that, in all, upwards of one hundred and fifty-two millions of gold coins have been coined at the expence of the state, and issued since the remission of the seignorage. We shall be considerably within the mark, if we estimate the average annual expence attending this coinage at L.12,000,¹ and, on this supposition, it will be found that the expence of the coinage of gold only has amounted, during the one hundred and fifty-two years which have elapsed since the accession of James II., to £1,824,000. But, if a low seignorage of no more than three or four per cent. had been charged on the gold coins, it would have produced four and a half or six millions; a sum which might have been collected without injury to any individual, and which, besides defraying the entire expences of the coinage, would have left a considerable surplus revenue.

Expence of the coinage of gold and silver.

In his evidence before the Lords' Committee in 1819, Mr. Mushet stated, that, with the improved machinery now in use in the mint, gold coin could be manufactured for about 10s. per cent. (*Minutes of Evidence*, p. 207.) And the expence of the manufacture of the silver coin may, we believe, be taken at about three times as much, or one and a half per cent. In France the coinage of gold costs 0.29 per cent., and silver 1.50 per cent.; in Russia the gold costs 0.85, and the silver 2.95 per cent. (*Storch*, tom. vi. p. 74.)

History of seignorage in England.

The precise period when a seignorage began to be charged upon English silver coins has not been ascertained. It must, however, have been very early. Mr. Ruding mentions, that in a mint account of the 6th Henry III., one of the earliest he had met with, the profit on £3,898, 0s. 4d. of silver coined at Canterbury, is stated to be £97, 9s., being exactly 6d. a-pound, of which the king had £60, 18s. 3½d., and the bishop the residue. (*Annals of the British Coinage*, vol. i. p. 179, 4to. ed.) In the 28th Edward I. the seignorage amounted to 1s. 2½d. per pound, 5½d. being allowed to the master of the mint, to indemnify him for the expences of coinage, and 9d. to the crown as its profit. Henry VI. increased the master's allowance to 10d. and 1s. 2d., and the king's to 1s. and 2s. In the reign of Edward IV. the seignorage varied from 4s. 6d. to 1s. 6d. It was reduced to 1s. in the reign of Henry VII.; but was prodigiously

augmented in the reigns of his successors, Henry VIII. and Edward VI., whose wild and arbitrary measures produced, as will be afterwards shewn, the greatest derangement of the currency. During the lengthened reign of Elizabeth, the seignorage varied from 1s. 6d. to 2s. per pound; at which sum it continued, with very little variation, until the 18th of Charles II. (1666), when it was totally remitted.

From this period down to 1817, no seignorage was charged on the silver coin; but a new system was then adopted. Silver having been underrated in relation to gold in the mint proportion of the two metals fixed in 1718, heavy silver coins were withdrawn from circulation, and gold only being used in all the larger payments, it became, in effect, what silver had formerly been, the standard of the currency. The act 56th Geo. III., regulating the present silver coinage, was framed not to interfere with this arrangement, but so as to render silver entirely subsidiary to gold. For this purpose it is made legal tender only to the extent of 40s.; and 66s. instead of 62s. are coined out of a pound of troy, the 4s. being retained as a seignorage, which, therefore, amounts to 6¼ per cent. The power to issue silver is vested exclusively in the hands of government; who have it, therefore, in their power to avoid throwing too much of it into circulation, and consequently to prevent its fusion, until the market price of silver shall have risen to above 5s. 6d. an ounce.

This arrangement was censured in the debates on the question of returning to cash payments in 1819. It was contended that the overvaluation of silver with respect to gold would render it the interest of every debtor to discharge his debts with silver, and that the gold coins would in consequence be driven from circulation, and exported to other countries. The result has shewn that this opinion was altogether erroneous. Debtors cannot discharge their debts by silver payments, for it is only legal tender to the extent of 40s.; and no creditor can be compelled, or would be disposed to take it in payment of a larger debt, except at its real value.²

In the 18th of Edward III., the period when we begin to have authentic accounts of the gold coinage, a pound troy of gold bullion was coined into florins, of the value of L.15: Of this sum only L.13, 16s. 6d. were given to the person who brought the bullion to be coined, L.1, 3s. 6d. being retained as seignorage, of which 3s. 6d. went to the Master, and L.1, to the King: But it appears, from the mint indentures, that the seignorage on the coinage of nobles for the same year amounted to only 8s. 4d. And, from this remote period to the accession of the Stuarts, with the exception of the coins issued in the 4th and 5th Edward IV. and the 34th, 36th, and 37th Henry VIII., the total charge of coining a pound weight of gold bullion seldom exceeded 7s. or 8s. money of the time. In the 2d James I., a pound weight of gold bullion was coined into L.40, 10s.; a seignorage of L.1, 10s. being deducted, 6s. 5d. of which went to the Master, and L.1, 3s. 7d. to the Crown. The seignorage on gold was remitted at the same time (18th Charles II.) with the seignorage on silver, and has not since been revived.³

As the regulation of the seignorage depended entirely on the will of the sovereigns, we need not be surprised at the variations in its amount at different periods, or that it should have fluctuated according to their necessities and caprices. It was, indeed, hardly possible that it should have been otherwise. Our ancestors were totally ignorant of the prin-

¹ Lord Liverpool states, that the entire expences of the mint, from 1777 to 1803, amounted to L.488,441, which gives an average expenditure of L.18,786 a-year. (*Liverpool on Coins*, p. 156.)

² Those who wish for a further elucidation of this subject, may refer to Mr. Mushet's evidence in the *Appendix to the Lords' Report on the Expediency of the Banks resuming Cash Payments*, where it is discussed at great length, and in the most able manner.

³ In the tables annexed to this article, the reader will find a detailed account of the amount of the seignorage and its fluctuations in different periods.

Money. ciple, by a strict adherence to which the imposition of a seignorage can alone be rendered advantageous. They considered it as a tax which might be increased and diminished at pleasure. And, far from taking any steps to limit the quantity of coin in circulation, so as to maintain its value, they frequently granted, to corporate bodies, and even to individuals,¹ the privilege of issuing coins, not subjected to a seignorage. No wonder, therefore, that it should have been considered as a most unjust and oppressive tax, and that its abolition should have been regarded as a very advantageous measure.

Remedy or
shere. Besides the revenue arising from the seignorage, our kings formerly derived a small revenue from the *remedy* or *shere*. It having been found impossible to coin money corresponding in every particular, of weight and purity, with a given standard, a small allowance is always made to the master of the mint, whose coins are held to be properly executed, provided their imperfections, whether on the one side or the other, do not exceed this allowance, or remedy. Its amount has varied very little since the reign of Edward III.; having, during this long period, generally been one-eighth part of a carat, or 30 grains of pure gold per pound of gold bullion, and two penny weight of pure silver per pound of standard silver bullion. By the law of 1816, the remedy for gold coins is fixed at 12 grains per lb. in the weight, and one-sixteenth part of a carat in the fineness. The remedy for silver is the same as before.

It does not appear that our princes derived any considerable advantage from the *remedy* previously to the reign of Elizabeth. But she, by reducing the master's allowance for the expence of coinage from 1s. 2d. to 8d. obliged him to come as near as possible to the *lowest* limit allowed by the remedy. Had the coins been delivered to those who brought bullion to the mint by *weight*, the queen, it is plain, would have gained nothing by this device; but, in the latter part of her reign, and the first seventeen years of that of her successor, James I., they were delivered by *tale*, so that the crown saved, in this way, whatever additional sum it might otherwise have been necessary to pay the master for the expences of coinage. In the great recoinage in the reign of William III., the profit arising from the remedy amounted to only 8s. on every hundred pounds weight of bullion; and the coinage is now conducted with so much precision, and the coins issued so near to their just weight, that no revenue is derived from this source.

Seignorage
in France. The continental princes have, we believe, without any exception, charged a seignorage on the coinage of money. In France, this duty was levied at a very early period. By an ordonnance of Pepin, dated in 755, a pound of silver bullion is ordered to be coined into twenty-two pieces, of which the master of the mint was to retain *one*, and the remaining twenty-one were to be delivered to the merchant bringing the bullion to the mint. (Le Blanc, p. 87.) There are no means of ascertaining the amount of the seignorage taken by the successors of Pepin, until the reign of Saint Louis (1226—1270), who coined the *marc* of silver into 58 sols, while he only delivered 54 sols, 7 deniers, to the merchant; at this period, therefore, the seignorage amounted to a sixteenth part of the *marc*, or to $6\frac{1}{4}$ per cent. It was subsequently increased or diminished without regard to any fixed principle. In the great recoinage in 1726, it amounted, on the gold coin, to $7\frac{5}{8}$ per cent., and to $5\frac{6}{7}$ per cent. on silver. In 1729, the mint price, both of gold and silver, were augmented, and the seignorage on the former reduced to $5\frac{1}{8}$

per cent., and on the latter to $4\frac{1}{8}$ per cent. A farther reduction took place in 1755 and 1771, when the seignorage on gold was fixed at $1\frac{4}{5}$ per cent., and on silver at $1\frac{7}{8}$ per cent. At this moment, the seignorage in France hardly covers the expence of coinage, being only about $\frac{1}{2}$ per cent. on gold, and $1\frac{1}{2}$ per cent. on silver.²

Money.

SECT. IV.—*Expence of a Currency consisting of the Precious Metals.*

The imposition of a moderate seignorage has, however, but a very inconsiderable effect in reducing the expence of a metallic currency. This, which is much greater than is generally imagined, does not consist in the coinage, which is comparatively trifling, but in the great amount of gold and silver required for the purpose. If, for example, the currency of Great Britain consisted wholly of gold, it would amount to at least fifty millions of sovereigns; and if the customary rate of profit were six per cent., it would cost three millions a-year: For had this fifty millions not been employed as money, it would have been vested in branches of industry in which, besides affording employment to thousands of individuals, it would have yielded six per cent. or three millions a-year, of nett profit to its possessors. But this is not the only loss. The fifty millions would not merely be withheld from the great work of production, and the country deprived of the revenue derived from its employment, but it would be perpetually diminished. The wear and tear of the coins is by no means inconsiderable; and supposing the expences of the coinage were defrayed by a moderate seignorage, the deficiency in the weight of the old worn coins must, on their being called in to be recoinced, be made up by the public. There is, besides, a constant loss from shipwrecks, fire, and other accidents. When due allowance is made for these causes of waste, it would not, perhaps, be too much to suppose, that a country, which had fifty millions of gold coins in circulation, would have annually to import the hundredth part of this sum, or half a million of coins to maintain its currency at its proper level.

Thus it appears, that were the customary rate of profit in Great Britain six per cent., it would cost $3\frac{1}{2}$ millions a-year to maintain fifty millions of gold coins in circulation. It is indeed true, that a reduction of the rate of profit would proportionally reduce the amount of this expence, though as the reduced expence would still bear the same proportion to the total income of the country that the higher expence did, the real cost of the currency would not be at all diminished. The case of France furnishes a still more striking example of the heavy charges attending the general use of a metallic currency. The amount of the gold and silver currency of that kingdom has been estimated by Necker at 2,200 millions of francs, and by Peuchet at 1,850 millions. (*Statistique Elémentaire de la France*, p. 473.) Now, supposing the lowest estimate to be the most correct, and taking the rate of profit at six per cent., this currency must cost France an hundred and eleven millions of francs a-year, exclusive of the wear and tear and loss of the coins, which being taken, as before, at the hundredth part of the entire mass, will make the whole annual expence amount to the sum of an hundred and twenty-two millions of francs, or to nearly *five millions* sterling. This heavy expence certainly forms a very material deduction from the advantages resulting from the use of a currency consisting entirely of the precious metals, and has doubtless been the chief

¹ Ruding's *Annals of the Coinage*, vol. i. p. 185. When the right of seignorage was abolished, there was a pension, payable out of the profits derived from it, granted under the great seal, for twenty-one years, to Dame Barbara Villiers, which the legislature ordered to be made good out of the coinage duties imposed by that act. (See Ruding, *in loco citato*, and Leake's *Historical Account of English Money*, 2d ed. p. 356.)

² Necker, *Administration des Finances*, (tom. iii. p. 8.)—Dr. Smith has stated (vol. ii. p. 438), on the authority of the "*Dictionnaire des Monnoies*, par Abot de Bazinchen," that the seignorage on French silver coins, in 1775, amounted to about eight per cent. The error of Bazinchen has been pointed out by Garnier, in his translation of the *Wealth of Nations*.

Money. cause why all civilized and highly commercial countries have endeavoured to fabricate a portion of their money of less valuable materials. It has not, however, been the only cause. It is obvious, that were there nothing but coins in circulation, the conveyance of large sums from place to place to discharge accounts, would be a very laborious process; and that even small sums could not be conveyed without considerable difficulty. Of the substitutes calculated alike to save expence and to lessen the cost of carriage, paper is in every respect the most eligible, and has been by far the most generally adopted. By using it instead of gold, we substitute the cheapest in the place of the most expensive currency; and enable the society to exchange all the coins which the use of paper renders superfluous, for raw materials, or manufactured goods, by the use of which both its wealth and enjoyments are increased. It is also transferred with the utmost facility. Hence since the introduction of bills of exchange, most great commercial transactions have been adjusted by means of paper only; and has also been used to a very great extent in carrying on the ordinary business of society.

SECT. V.—*Paper Money. Principle on which its Value is maintained.*

Origin of paper money, and principle on which banking is carried on.

In the earliest periods, subsequent to the invention of writing and paper, the pecuniary engagements of individuals would be committed to the latter. This gives security to the creditor, that he shall be able to claim the full amount of his debts, and to the debtor, that he shall not be liable to any overcharge; and avoids the differences which are sure to arise where the terms of contracts are not distinctly specified. But a very short time only would elapse before individuals, having written obligations from others, would begin to transfer them to their debtors; and after the advantages derivable from employing them in this way had been ascertained, it was an obvious source of emolument for persons in whose wealth and discretion the public had confidence to issue their obligations to pay certain sums, in such a form as might fit them for performing the functions of a circulating medium in the ordinary transactions of life. No one would refuse to accept as money the promissory note or obligation of an individual of large fortune, and of whose solvency no doubt could be entertained. But as full value must have been originally given for the promissory note, it is clear that whilst its continuance in circulation could be no loss to the public, it would be a very great source of profit to the issuer.

Suppose, for example, that a merchant issues a promissory note for L.10,000, he must, previously to putting it in circulation, either have received an equivalent sum of money, or of some sort of produce possessed of real value, or, which is by far the most common case, he must have advanced it to an individual who has given him security for its repayment with interest. In point of fact, therefore, the issuer has exchanged his *promise to pay* L.10,000 for the profits to be derived from the employment of a real capital of that amount; and as long as the promissory note, the intrinsic worth of which cannot well exceed a sixpence, remains in circulation, he will, supposing profits to be five per cent., receive from it a revenue of L.500 a-year. It is on this principle that the business of banking is conducted. A banker could make no profit were he obliged to keep dead stock or bullion in his coffers, equal to the amount of his notes in circulation. But if he be in good credit, a fourth or a fifth part of this sum will perhaps be sufficient; and his profits, after the expenses of the establishment, and of the manufacture of his notes, are deducted, will be measured by the *excess* of the profit derived from his notes in circulation, over that which he might have realised by employing the stock kept in his coffers to meet

the demands of the public. "A bank would never be established, if it obtained no other profits but those derived from the employment of its own capital: its real advantage commences only when it employs the capital of others." (*Proposals for an Economical and Secure Currency*, p. 87.)

As no means have been devised to limit the supply of the promissory notes issued by private individuals, their value, it is plain, could not be maintained were the issuers to fall into discredit, or relieved from their promise to pay them. But it is otherwise with the promissory notes issued by the state, or by a company acting under its control. The quantity of such notes may be effectually limited; and we have seen that, when this is the case, intrinsic worth is not necessary to a currency, and that, by properly regulating the supply of paper declared to be legal tender, its value may be sustained on a par with gold, or any other commodity. It was by acting on this principle of limitation, that the value of the paper of the bank of England was maintained in the interval between the passing of the restriction act in 1797, and the commencement of bullion payments in 1820. No rational explanation of this circumstance, so much at variance with all the old theories of paper money, can be deduced from any other principle. The fact of their being depreciated never creates any indisposition on the part of the public to apply for accommodation to a bank whose notes are legal tender. The presenter of a bill for discount is indifferent whether the notes given in exchange for it are payable in specie or not. His object, in resorting to the bank, is to exchange his promissory note for money; that is, for paper that will be received in payment of his debts, or of whatever he may wish to purchase. It is, therefore, of no consequence to him, whether the issuers of paper, have, by issuing in excess depressed its value relatively to gold, or whether they have so restricted their issues as to sustain its value on a level with the value of that metal. These circumstances, it is true, affect the interests of all those classes whose incomes do not vary with the variations in the value of money; but, in as much as the prices of goods rise and fall with the increase or diminution of paper, merchants, who are the principal demanders of discounts, are comparatively but little affected by its fluctuations. The presenter of a bill for L.500 or L.1000 to a bank, has received it, if it have arisen out of a real commercial transaction, in lieu of a certain quantity of goods, which, at the then value of money, were worth L.500 or L.1000; and it is this sum which, by presenting the bill to the bank, he wishes to obtain. If the value of money had been different, the price of the goods, and consequently the sum for which the bill was drawn, would also have been different. It is to this market value of money at the time that attention is exclusively paid in commercial transactions. When, in 1809, 1810, 1811, 1812, 1813, and 1814, Bank of England paper was depressed from excess from ten to twenty-five per cent. below the value of bullion, the circumstance of an act of Parliament having declared, that it should be paid in cash at the restoration of peace, had as little effect in raising its value, as its depreciation had in diminishing the applicants for discounts. The truth is, that individuals never resort to a bank for paper money, unless they have immediate occasion for it. As soon as it has been obtained, they throw it upon the market, for whatever it will bring; and as they purchased it on the same terms, (for it is seldom that the value of money is materially affected in the short interval between the time when a bill is discounted and becomes due,) they generally get as much for it, and perhaps more, than it cost. We shall immediately explain what constitutes the natural limit to the applications for discounts; but we have said enough to show, that it has nothing to do with the convertibility of notes into cash.

Those who have recourse to a bank to obtain discounts

Money.

Limitation of supply sufficient to sustain the value of bank paper.

Money. of accommodation bills, consider like the presenters of real bills, only the present value of money. Accommodation bills are never discounted, excepting in the view of immediately employing the money, either in the purchase of commodities, or of labour, or in the payment of debts; and, whether one pound notes be of the value of 10s. or 20s. is obviously of no consequence; in as much as the amount of the bill presented for discount is regulated accordingly.

The circumstance that country bank notes cease to circulate as soon as any suspicion is entertained of the solvency of their issuers, is nowise inconsistent with this principle. Country bank notes are exchangeable, at the pleasure of the holder, for Bank of England notes; but from the restriction in 1797 down to 1820, the latter not being exchangeable for any thing else, constituted the real standard of value. Hence when a country bank lost credit, the circulation of its notes was stopped, from its being believed that it would be impossible to obtain Bank of England paper in their stead; or, in other words, that they would not exchange for that description of paper which constituted the real medium of exchange. But, it is impossible to imagine, that this paper should itself be affected by a want of credit. Every one knew that it had no intrinsic worth; and as already shown, its value was regulated, (and must, whenever it is not rendered exchangeable for a given quantity of some other commodity, continue to be exclusively regulated,) by the amount in circulation compared with the demand.

It appears, therefore, that if there were perfect security, that the power of issuing paper money would not be abused; that is, if there were perfect security for its being issued in such quantities, as to preserve its value relatively to the mass of circulating commodities nearly equal, the precious metals might be entirely dispensed with, not only as a circulating medium, but also as a standard to which to refer the value of paper.

Difficulty of limiting the supply of bank paper, otherwise than by rendering it exchangeable for gold or silver. Unfortunately, however, no such security can be given. This is a point, respecting which there can be no difference of opinion. We have it in our power to appeal to a widely extended and uniform course of experience; to the history of Great Britain, and of every other country in Europe, and to that of the United States; to show that no man, or set of men, have ever been invested with the power of making unrestricted issues of paper money without abusing it; or, which is the same thing, without issuing it in inordinate quantities. If the power to supply the state with paper money be vested in a private banking company, then to suppose that they should, by limiting their issues, endeavour constantly to sustain the value of paper, would be to suppose that they should be attentive only to the public interest, and neglect their own private interest. The re-enactment of the restriction act, would not have the least effect on the value of paper, provided its quantity were not at the same time increased. But who can doubt that, in such circumstances, it would be increased? Such a measure would enable the Bank of England to exchange bits of engraved paper, not worth perhaps five shillings a quire, for as many, or the value of as many hundreds of thousands of pounds. And is it to be supposed, that the directors and proprietors of the bank should not avail themselves of such an opportunity to amass wealth and riches? If government enable a private gentleman to exchange a bit of paper for an estate, will he be deterred from doing so by any considerations about its effect in sinking the value of the currency? In Loo Choo we might perhaps meet with such an individual, but if we expect to find him in Europe, we shall most likely be disappointed. Here we are much too eager in the pursuit of fortune to be at all influenced by such scruples. It is essential, therefore, that the issuers of paper money should be placed under some check or control; and the comparatively steady value of the precious metals, at once suggests that none can be so effectual as to lay them under the ob-

ligation of exchanging their notes, at the pleasure of the holder, for a *given and unvarying quantity* of gold or silver.

It has, however, been contended, that there is a material difference between paper issued by government in payment of its debts, and that issued by a private banking company in discount of good bills. In regard to the former, it is admitted on all hands that it may be issued in excess; but in regard to the latter, it has been strenuously urged, that "notes issued only in proportion to the demand, in exchange for good and convertible securities, payable at specific periods, cannot occasion any excess in the circulation, or any depreciation." As all the arguments advanced by those who contended that the paper of Great Britain was not depreciated between 1797 and 1819, involve this principle, it may be worth while to examine it a little minutely.

In the first place, it may be observed, that the demand for discounts does *not* depend on the nature of the security required for their repayment, but on the rate of interest for which they may be obtained, compared with the ordinary rate of profit made by their employment. If an individual can borrow £10,000, £100,000, or any greater sum, at 4, 5, or 6 per cent., and if he can realise 7, 8, or 10 per cent. by its employment, it is evidently for his interest, and it would be for the interest of every other person similarly situated, to borrow to an unlimited extent. But a banking company, relieved of all obligation to pay its notes in cash, and not, of course, obliged to keep any unproductive stock or bullion in its coffers, would be able to issue its notes at the lowest possible rate of interest; and the demand for its paper would therefore be proportionally great.

"The interest of money," says Mr. Ricardo, "is not regulated by the rate at which the bank will lend, whether it be 5, 4, or 3 per cent., but by the rate of profit which can be made by the employment of capital, and which is totally independent of the quantity or of the value of money. Whether the bank lent one million, ten millions, or a hundred millions, they would not permanently alter the market rate of interest; they would alter only the value of the money which they thus issued. In one case, ten or twenty times more money might be required to carry on the same business than what might be required in the other. The applications to the bank for money, then, depend on the comparison between the rate of profit that may be made by the employment of it, and the rate at which they are willing to lend it. If they charge less than the market rate of interest, there is no amount of money which they might not lend; if they charge more than that rate, none but prodigals and spendthrifts would be found to borrow of them. We accordingly find that when the market rate of interest exceeds the rate of five per cent., at which the bank uniformly lends, the discount office is besieged with applicants for money; and, on the contrary, when the market rate is even temporarily under five per cent., the clerks of that office have no employment." (*Principles of Political Economy*, p. 511.)

From 1809 to 1815 inclusive, the period in which the value of our paper currency relatively to gold was lowest, the market rate of interest considerably exceeded the rate (five per cent.) at which the Bank of England and most of the country banks invariably lent. Although, therefore, the amount of paper currency had, in that interval, been very much increased, the applicants for fresh discounts continued as numerous as ever. And there seems no reason to doubt, had the directors not been apprehensive that, ultimately, they might have to pay their notes in specie, that the amount in circulation would have been very much increased; at least, such would certainly have been the case, had they acted to the full extent of their avowed opinion, that it was impossible to issue too much paper, or to reduce its value, by engrossing into the circulation such quantities as were issued in discount of good bills. The wants of commerce are altogether insatiable. Inconvertible paper money, provided

Money. Proposition maintained by those who deny that bank paper can be depreciated.

Demand for discounts depends on a comparison between the rate of interest and the rate of profit.

Money. the rate of interest at which bills are discounted be less than the market rate, can never be too abundant. As long as this is the case, million after million may be thrown upon the market. The value of the currency may be so reduced as to require a one pound note to purchase a quatern loaf; but the circumstance of its value being diminished in proportion to the increase of its quantity, would render the demand for additional supplies as great as ever.

Were the Bank of England to discover a process whereby sovereigns could be manufactured with the same facility as notes, it could not be disputed that it would be in her power to depreciate the value of gold, by making large issues of what had been produced at so very little cost. Now, in what respect would this fictitious case differ from the actual situation of the Bank, were the restriction act renewed and made perpetual? The Bank would then be able, without check or control, to exchange her paper for landed property, manufactured goods, government securities, &c. But we have seen, that the value of this paper, like the value of gold, in the hypothetical case, depends entirely on the proportion which the supply bears to the demand; and, as the demand is not affected by an increase of quantity, for that increase, by diminishing its value, renders the larger quantity of as little efficacy as the smaller quantity, it is abundantly clear, that if the Bank lent at a sufficiently low rate of interest, there could be no limit to her issues.

Necessity of making bank notes payable in gold or silver.

On the whole, therefore, it is plain, whether the power of issuing paper be vested in the hands of a private banking company, or of government, that it must be placed under some efficient control, such as the obligation to pay in gold or silver. It is easy to discover the manner in which a check of this kind limits the issue of paper, and sustains its value. Whenever the Bank has issued so much paper as to sink its value relatively to bullion, its notes begin to return upon it, to have them exchanged for a higher value; and the Bank is, in consequence, obliged, to prevent the exhaustion of its coffers, to contract its issues, and raise its paper to a level with gold. An extremely small profit, or an extremely small depreciation of paper, as compared with gold or silver, is sufficient to make the holders of bank paper send it to be exchanged for those metals; and hence the value of bank notes convertible at pleasure into a *given and unvarying quantity* of gold or silver, can never differ considerably from its value. The issues of the Bank of England were for more than a century previously to 1797, limited in the manner now explained, and during that whole period they were hardly ever depreciated $\frac{1}{4}$ per cent., and never more than two per cent., and that but for a few days only.

Scheme for paying notes in gold bars.

But though it be thus necessary, in order to avoid all sudden and injurious fluctuations in the value of paper, that it should be made exchangeable at the pleasure of the holder for gold or silver, and it is not essential to this end that it should be made exchangeable for gold or silver coins. Previously to the resumption of specie payments by the Bank of England in 1821, she was obliged to give bars of assayed bullion in exchange for her notes, according to a plan suggested by the late Mr. Ricardo; and there can be no doubt that this obligation would have sustained the value of paper quite as effectually as it is sustained by the obligation to pay in coin of the legal weight and purity, at the same time that it would have saved the greater part of the heavy expense occasioned by the use of metallic money. But, how important soever, these were not the only considerations that had to be attended to. The discovery of means for the prevention, or at least diminution, of the forgery to which the substitution of notes in the place of guineas had given rise, was indispensably necessary to the maintenance of Mr. Ri-

cardo's plan; and notwithstanding all the efforts that have been made, this desideratum has not yet been supplied. Forgery in the larger description of notes, or in those for £5 and upwards, may with due precaution be prevented from becoming injuriously prevalent. But low notes, or those of the value of £1 or £2, having to circulate amongst the labouring classes, and in immense numbers, present facilities for the issue of spurious paper, which it has been found impossible materially to diminish. Hence, in 1821, the plan of paying in bars of bullion was abandoned, and the Bank of England recommended paying in specie.¹

SECT. VI.—*Whether Gold or Silver should be adopted as the Standard of the Currency, or whether it should consist of both.*

As the value of gold and silver, or the cost of their production, is perpetually varying, not only relatively to other commodities, but also relatively to each other, it is impossible arbitrarily to fix their comparative value. Gold may now, or at any given period, be to silver as 14 or 15 is to 1; but were sovereigns and shillings coined in that proportion, the discovery of a gold or silver mine of more than the ordinary degree of productiveness, or the discovery of any abridged process, by which labour might be saved in the production of one of the metals, would derange this proportion. As soon, however, as the mint proportion between the different metals ceases to be the same with that which they bear to each other in the market, then it becomes the obvious interest of every debtor to pay his debts in the metal whose mint valuation is highest.

In 1718, in pursuance of the advice of Sir Isaac Newton, the value of the guinea was reduced from twenty-one shillings and sixpence to twenty-one shillings; the value of fine gold to fine silver was consequently rated, in our mint, at $15\frac{2}{3}$ to 1, and both metals were declared to be legal tender in that proportion. But, notwithstanding this reduction, the guinea was still rated at a higher value, compared with silver, than it ought to have been. This higher value was estimated, by Lord Liverpool, to have been, at the time, equal to fourpence on the guinea, or to $1\frac{1}{2}$ per cent.; and as the value of silver compared with gold, continued to increase during the greater part of last century, it afterwards became considerably greater. The over-valuation of gold, by making it for the interest of every one to pay his debts in it rather than in silver, made gold be used in all considerable payments, and was the cause that, during the long period from 1718 down to the late recoinage, no silver coins of the legal weight and fineness would remain in circulation. The silver currency consisted entirely of light, worn coins; and when, in 1797, the further coinage of silver was forbidden, the silver currency was very much debased. But, as it existed only in a *limited quantity*, it did not, according to the principle already explained, sink in its current value. Though debased, it was still the interest of debtors to pay in gold. If, indeed, the quantity of debased silver had been very great, or if the mint had issued such debased pieces, it might have been the interest of debtors to pay in such debased money. But its quantity being limited, it sustained its value; and gold was practically the real standard of the currency.

The act of 1774, declaring that silver should not be legal tender for any debt exceeding £25, *unless by weight according to the mint standard*, had not, as has been supposed, any effect in causing the general employment of gold as money, in preference to silver. For, to use the words of Mr. Ricardo, "this law did not prevent any debtor from paying any debt, however large its amount, in silver currency fresh

¹ It was intended to have given in this place some account of the Bank of England, and of the provincial banks; but as inquiries are at present (February 1837) in progress, which may throw considerable light on these establishments, and measures are believed to be in contemplation by which they may be materially affected, it has been judged better to postpone all notice of them to the article PAPER MONEY.

Money. from the mint. That the debtor did not pay in this metal was not a matter of chance, nor a matter of compulsion, but wholly the effect of choice. It did not suit him to take silver to the mint, but it did suit him to take gold hither. It is probable that if the quantity of this debased silver in circulation had been enormously great, and also a legal tender, that a guinea would have been, as in the reign of William III., worth thirty shillings; but it would have been the debased shilling that had fallen in value, and not the guinea that had risen." (*Principles of Political Economy*, p. 520).

Contrary effect produced by the over-valuation of silver in the French mint. In France a different valuation of the precious metals had a different effect. The louis d'or, which, previously to the recoinage of 1785, was rated in the mint valuation at 24 livres, was really worth 25 livres 10 sols. Those, therefore, who chose to discharge the obligations they had contracted, by payments of gold rather than of silver, plainly lost 1 liv. 10 sols on every sum of 24 livres. In consequence very few such payments were made, gold was nearly banished from circulation, and the currency of France became almost exclusively silver. (Say, tom. i. p. 393.) In 1785, a sixteenth part was deducted from the weight of the louis d'or, and since that period the value of the precious metals, as fixed in the French mint, has more nearly corresponded with the proportion which they bear to each other in the market. Indeed, it was stated, in evidence before the Committee of the House of Commons in 1819 (*Report*, p. 192), that the difference between the mint and market proportions of gold and silver at Paris in 1817 and 1818, had not exceeded from one-tenth to one-fourth per cent. There is, however, no reason to presume that this coincidence, which must have been in a great degree accidental, can be maintained under any arbitrary system. To ensure the indifferent use of gold and silver coins in countries where they are both legal tender, their mint values would require to be every now and then adjusted, so as to correspond with their real values. But as this would obviously be productive of much trouble and inconvenience, the preferable plan undoubtedly is to make only one metal legal tender, and to allow the worth of the other to be adjusted by the competition of the sellers and buyers.

The absurdity of employing two metals as legal tender, or as a standard of value, was unanswerably demonstrated by Mr. Locke and Mr. Harris, and has been noticed by every subsequent writer; but so slow is the progress of improvement, that it was not till the year 1816 that it was enacted that gold only should be legal tender for all sums exceeding 40s.

Silver preferable to gold as a standard. Whether, however, gold should have been adopted as the standard of exchangeable value, in preference to silver, is a question not so easy of solution, and on which there is a great diversity of opinion. Mr. Locke, Mr. Harris, and Mr. Ricardo, are of opinion that silver is better fitted than gold for a standard; whilst Dr. Smith, although he has not explicitly expressed himself, appears to think that gold ought to be adopted in preference. This opinion has been very ably supported by Lord Liverpool, in his valuable work *On the Coins of the Realm*; and his reasonings having received the approbation of parliament, and gold having been made legal tender, all attempts to alter this arrangement ought to be opposed.

A gold and silver currency equal in value. Whether gold or silver be adopted as the standard of the currency, does not affect its total cost or value; for, the quantity of metal employed as money, or the quantity of metal for which paper is the substitute, is always inversely as the value or cost of such metal. When gold is the standard, fourteen or fifteen times less of it than of silver is

required; or, which is the same thing, if the denomination of a pound be given to any *specific weight* of gold or silver, fifteen times more of such silver pounds will be required to serve as currency, fifteen to one being about the proportion which gold bears in value to silver. Hence the expence of a gold or silver currency is identical. Gold being too valuable in proportion to its bulk, to be coined into pieces of the value of a shilling or a sixpence, the subsidiary currency necessary in small payments, should be overvalued, and issued only in limited quantities, as is the case with the present silver coinage.

Were a seignorage charged on the gold coins, paper, it is obvious, might be depreciated to the full extent of that seignorage, before it would be the interest of the holders to demand coin for the purpose of exportation, and consequently before the check of specie payments could begin to operate. But, even with such a seignorage, the risk of paper being depreciated, might be obviated, by making it obligatory on the Bank to pay their notes, either in bullion, at the mint price of L.3, 17s. 10½d. an ounce, or coin, at the pleasure of the holder. A regulation of this kind could not be justly considered as imposing any hardship on the Bank; for it is plain, that no bullion would be demanded from her, except when, by the issue of too much paper, its value had been sunk below the standard.

SECT. VII.—*Standard of Money. Degradation of the Standard in Italy, France, Great Britain, and other countries. Pernicious effects of this degradation.*

By the standard of money is meant the degree of the purity or fineness of the metal of which coins are made, and the quantity or weight of such metal contained in these coins. Twelve ounces of the metal, of which standard English silver coins are made, contains 11 ounces 2 dwts. fine, and 18 dwts. alloy; and a pound troy of this standard silver, or pound sterling, contains 66 shillings, or $\frac{22}{9}$ parts of $\frac{1}{2}$ of a pound troy of fine silver, that is, 1614 $\frac{2}{3}$ grains.¹ From the 43 of Elizabeth down to 1816, when the act 56th Geo. III. cap. 68, imposing a seignorage of about six per cent. on the silver coin, was passed, the pound weight of standard silver bullion was coined into 62 shillings. All the English silver coins have been coined out of silver of 11 oz. 2 dwts. fine, from the Conquest to this moment, excepting for a period of sixteen years, from 34th Henry VIII. to the 2d Elizabeth.

The purity of gold is not estimated either in Great Britain, or in most other European countries, by the weights commonly in use, but by an Abyssinian weight, called a *carat*.¹ The carats are subdivided into four parts, called grains, and these again into quarters; so that a *carat grain*, with respect to the common divisions of a pound troy, is equivalent to $2\frac{1}{2}$ penny-weights. Gold of the highest degree of fineness, or pure, is said to be 24 carats fine. When gold coins were first made at the English mint, the standard of the gold put in them was of 23 carats $3\frac{1}{2}$ grains fine, and $\frac{1}{2}$ grain of alloy; and so it continued without any variation to the 18th Henry VIII., when a new standard of gold of 22 carats fine, and two carats alloy was introduced. The first of these was called the old standard; the second the new standard, or crown gold, because crowns, or pieces of the value of five shillings, were first coined of this new standard. Henry VIII. made his gold coins of both these standards under different denominations; and this practice was continued by his successors until the year 1633. From that period to the present, gold coins have been invariably made of the new standard, or crown gold; although some of the

¹ The carat is a bean, the fruit of an Abyssinian tree, called Kuara. This bean, from the time of its being gathered, varies very little in its weight, and seems to have been in the earliest ages, a weight for gold in Africa. In India it is used as a weight for diamonds, &c. (Bruce's *Travels*, vol. v. p. 66.)

Money. coins made of the old standard previously to 1633 continued to circulate till 1732, when they were forbidden to be any longer current. (*Liverpool on Coins*, p. 27.)

Weight of English coins. The standard of our present gold coins is, therefore, eleven parts of fine gold, and one part of alloy. The pound troy of such gold is divided into $46\frac{8}{9}$ sovereigns, each of which ought, consequently, when fresh from the mint, to

weigh $\frac{1}{46\frac{8}{9}}$ of twelve ounces, or five dwts. $3\frac{1}{2}\frac{1}{3}$ grains of

standard gold, or four dwts. $17\frac{1}{12}\frac{1}{4}$ grains of pure gold.

The alloy in coins is reckoned of no value. It is allowed, in order to save the trouble and expence that would be incurred in refining the metals, so as to bring them to the highest degree of purity; and because, when its quantity is small, it has a tendency to render the coins harder, and less liable to be worn or rubbed. If the quantity of alloy were considerable, it would lessen the splendour and the ductility of the metals, and would add too much to the weight of the coins.

Having thus ascertained what the standard of money really is, we shall now proceed to examine the effects produced by variations in the standard. This is, both in a practical and historical point of view, a very important inquiry.

Variations of the standard; general remarks.

To make any direct alteration in the terms of the contracts entered into between individuals, would be too barefaced and tyrannical an interference with the rights of property, to be tolerated. Those, therefore, who endeavour to enrich one part of society, at the expence of another, find it necessary to act with great caution and reserve, and to substitute artifice for open and avowed injustice. Instead of directly altering the stipulations in contracts, they have ingeniously bethought themselves of altering the standard, by which these stipulations were adjusted. They have not said, in so many words, that ten or twenty per cent. should be added to or deducted from the mutual debts and obligations of society, but they have, nevertheless, effected this by making a proportional change in the value of the currency. Men, in their bargains do not, as has been already seen, stipulate for signs or measures of value, but for real equivalents. Money is not merely the standard by a comparison with which the value of commodities is ascertained; but it is also the equivalent, by the delivery of a fixed amount of which the stipulations in most contracts and engagements may be discharged. It is plain, therefore, that no variation can take place in its value, without affecting all these stipulations. Every addition to the value of money makes a corresponding addition to the debts of the state, and of every individual; and every diminution of its value makes a corresponding diminution of those debts. Suppose that, owing to an increase in the difficulty of producing gold and silver, or in the quantity of bullion contained in coins of the same denomination, the value of money is raised twenty per cent., it is plain that this will add twenty per cent. to the various sums which one part of society owes to another. Though the nominal rent of the farmer, for example, continue stationary, his real rent is increased. He continues to pay the same number of pounds or livres as formerly; but these have become more valuable, and require to obtain them the sacrifice of a fifth part more corn, labour, or other things the value of which has remained stationary. On the other hand, had the value of money fallen twenty per cent., the advantage, it is plain, would have been all on the side of the farmer, who would have been entitled to a discharge from his landlord, when he had paid him only four-fifths of the rent really bargained for.

But, notwithstanding it is thus obviously necessary, in order to prevent a pernicious subversion of private fortunes, and the falsifying of all precedent contracts, that the standard of money, when once fixed, should be maintained inviolate,

there is nothing that has been so frequently changed. We do not here allude to variations affecting the value of the bullion of which the standard is composed, and against which it is impossible to guard, but to variations in the quantity of bullion contained in the same nominal sum of money. In almost every country, debtors have been enriched at the expence of their creditors. The necessities, or the extravagance of governments, have forced them to borrow; and to relieve themselves of their incumbrances, they have almost universally had recourse to the disgraceful expedient of degrading the coin; that is, of *cheating* those who had lent them money, and of enabling every other debtor in their dominions to do the same.

The ignorance of the public in remote ages greatly facilitated this species of fraud. Had the names of the coins been changed when the quantity of metal contained in them was diminished, there would have been no room for misapprehension. But, though the weight of the coins was undergoing perpetual, and their purity occasional reductions, their ancient denominations were almost uniformly preserved: and those people who saw the same names still remaining after the substance was diminished; who saw coins of a certain weight and fineness circulate under the names of florins, livres, and pounds, and who saw them continue to circulate as such, after both their weight and the degree of their fineness had been lessened, began to think that they derived their value more from the stamp affixed to them, by authority of government, than from the quantity of the precious metals they contained. This was long a very prevalent opinion. But the rise of prices which invariably followed every reduction of the standard, and the derangement which was thereby occasioned in every pecuniary transaction, undeceived the public, and taught them, though it may not yet have taught their rulers, the expediency of preserving the standard of money inviolate.

Before proceeding to notice the changes made in the currency of this and other countries, it may be proper to observe, that the standard is generally debased in one or other of the undermentioned ways.

First, by simply altering the denominations of the coins, without making any alteration in their weight or purity. Thus, suppose sixpence, or as much silver as there is in a sixpence, were called a shilling, then a shilling would be two shillings, and twenty of these shillings, or ten of our present shillings, would constitute a pound sterling. This would be a reduction of fifty per cent. in the standard.

Secondly, the standard may be reduced, by continuing to issue coins of the same weight, but making them baser, or with less pure metal and more alloy.

Thirdly, it may be reduced, by making the coins of the same degree of purity, but of diminished weight, or with less pure metal; or it may be reduced partly by one of these methods, and partly by another.

The first of these methods of degrading the standard was recommended by Mr. Lowndes in 1695, and if injustice is to be done, it is certainly, on the whole, the least mischievous mode by which it can be perpetrated. It saves all the trouble and expence of a recoinage; but as it renders the fraud too obvious, it has been but seldom resorted to. In inquiries of this kind, however, it is rarely necessary to investigate the manner in which the standard has been degraded. And by its reduction or degradation, we uniformly mean, unless when the contrary is distinctly expressed, a diminution of the quantity of pure metal contained in coins of the same denomination without regard to the particular mode in which such diminution may have been effected.

In conformity with what has been observed in the first section of this article, relative to the universality of the ancient practice of weighing the precious metals in every exchange, it is found that the coins of most countries have the same names as the weights commonly used in them. To

Money. these weights the coins at first exactly correspond. Thus the *talent* was a weight used in the earliest periods by the Greeks, the *as* or *pondo* by the Romans, the *livre* by the French, and the *pound* by the English, Scotch, &c.; and the coins originally in use in Greece, in Italy, in France, and in England, received the same denominations, and weighed precisely a talent, a pondo, a livre, and a pound. The standard has not, however, been preserved inviolate, either in ancient or in modern times. But the limits within which an article of this kind must be confined, prevents us from tracing the various changes in the money of this and other countries, with the minuteness which the importance of the subject deserves, and obliges us to notice only those which were most prominent.¹

History of
the money
of Rome.

Weight of
the as.

ROMAN MONEY.—We learn from Pliny, that the first Roman coinage took place in the reign of Servius Tullius, that is, according to the common chronology, about 550 years before Christ. The *as*, or *pondo*, of this early period, contained a Roman pound of copper, the metal then exclusively used in the Roman coinage, and was divided into twelve parts or *unciae*. If we may rely on Pliny, this simple and natural system was maintained until 250 years before our era, or until the first Punic war, when the revenues of the state being insufficient, government attempted to supply the deficiency, by reducing the weight of the *as* from twelve to two ounces. But it is extremely improbable that a government, which had maintained its standard inviolate for 300 years, should have commenced the work of degradation, by at once reducing it to a sixth part of its former amount; and it is equally improbable that so sudden and excessive a reduction should have been made in the value of the current money of the state, and, consequently, in the debts due by individuals to each other, without occasioning the most violent commotions. Nothing, however, is said in any ancient writer, to entitle us to infer that such commotions actually took place; and we, therefore, concur with those who think that the weight of the *as* had been previously reduced, and that its diminution, which, it is most probable, would be gradual and progressive, had merely been carried to the extent mentioned by Pliny during the first Punic war. In the second Punic war, or 215 years before Christ, a further degradation took place, and the weight of the *as* was reduced from two ounces to one ounce. And by the Papyrian law, supposed to have passed when Papyrius Turdus was tribune of the people, or 175 years before Christ, the weight of the *as* was reduced to half an ounce, or to $\frac{1}{4}$ th of its ancient weight, at which it continued till Pliny's time and long afterwards.²

Proportion
of silver to
copper.

The denarius, the principal silver coin in use amongst the Romans, for a period of 600 years, was coined five years before the first Punic war, and was, as its name imports, rated in the mint valuation at ten asses. Mr. Greaves, whose dissertation on the denarius has been deservedly eulogised by Gibbon, (*Decline and Fall*, vol. iii. p. 89), shews that the denarius weighed at first only one-seventh part of a Roman ounce,³ which, if Pliny's account of the period when the

weight of the *as* was first reduced be correct, would give the value of silver to copper in the Roman mint as 840 to 1, which Mr. Greaves very truly calls a "most unadvised proportion." But if we suppose, with Mr. Pinkerton, (*Essay on Medals*, vol. i. p. 132, edit. 1789), that when the denarius was first issued, the *as* only weighed three ounces, the proportion of silver to copper would be as 252 to 1, a proportion which, when the *as* was soon afterwards reduced to two ounces, would be as 168 to 1, or about a third more than in the British mint. When, in the second Punic war, the *as* was reduced from two ounces to one, the denarius was rated at sixteen asses.

During his stay in Italy, Mr. Greaves weighed many of the consular denarii, that is, as he explains himself, of the denarii that were struck after the second Punic war, and previously to the government of the Cæsars; and he found, by frequent and exact trials, the best and most perfect of them that weighed 62 grains English troy weight. (Greaves' *Works*, vol. i. p. 262). Now, as the English shilling (new coinage) contains very nearly $87\frac{1}{4}$ grains standard silver, this would give $8\frac{1}{2}$ d. for the value of the consular denarius. We should, however, fall into the grossest mistakes, if we indiscriminately converted the sums mentioned in the Latin authors by this or any other fixed proportion. It is not enough to determine the real value of a coin, to know its weight; the degree of its purity or the fineness of the metal of which it is made, must also be known. But Mr. Greaves did not assay any of the denarii weighed by him. And though it were true, as most probably it is, that, from the first coinage of silver in the 485th year of the city to the reign of Augustus, the weight of the denarius remained constant at $\frac{1}{4}$ th part of a Roman ounce, or about 62 grains; and that, from the reign of Augustus to that of Vespasian, it only declined in weight from $\frac{1}{4}$ th to $\frac{1}{8}$ th of an ounce;⁴ still it is abundantly certain that its real value had been reduced to a much greater extent. As to this fact the authority of Pliny is decisive; for he expressly states, that Livius Drusus, who was tribune of the people in the 662d year of the city, or 177 years after the first coinage of silver, debased its purity, by alloying it with $\frac{1}{8}$ th part of copper. (lib. xxxij, cap. 3, previously quoted). And in a subsequent chapter (the ninth) of the same book, he informs us that Antony the triumvir mixed iron with the silver of the denarius; and that, to counteract these abuses, a law was afterwards made providing for the assay of the denarii. Some idea of the extent to which the purity of the coins had been debased, and of the disorder which had in consequence been occasioned, may be formed from the circumstance, also mentioned by Pliny, of statues being every where erected in honour of Marius Gratidianus, by whom the law for the assay had been proposed. But this law was not long respected; and many imperial denarii are now in existence, consisting of mere plated copper. (Bazinghen, *Dictionnaire des Monnoies*, tom. ii. p. 64.)

Gold was first coined at Rome sixty-two years after silver, in the 547th year of the city, and 204 years before the aureus.

¹ It is impossible in this place to enter into any discussion relative to the value of Grecian money. It is, however, a subject of no little interest and curiosity. M. Romé de l'Isle, in his *Traité de Métrologie*, published in 1789, has given an account of the weight and fineness of an immense number of Attic drachmas and tetradrachmas. But he does not seem to have been more fortunate than his predecessors in deducing the value of the *talent* from the weight of the drachmas. The errors and absurdities into which modern critics and commentators have fallen, in estimating the value of the sums mentioned in ancient authors, is indeed astonishing. They are ably pointed out in a short essay, *De la Monnoie des Peuples Anciens*, in one of the supplemental volumes added by Garnier to his translation of the *Wealth of Nations*.

² "Servius rex primus signavit æs. Antea rudi usus Romæ Remeus tradit. Signatum est nota pecudum unde et pecunia appellata. . . . Argentum signatum est anno urbis DLXXXV. Q. Fabio Cos. quinque annos ante primum bellum Punicum. Et placuit denarius pro x. libris æris, quinarium pro quinque, sestertium pro dipondio ac semisse. Libræ autem pondus æris imminutum bello Punico primo cum impensis resp. non sufficeret, constitutumque ut asses sextentario pondere ferirentur. Ita quinque partes factæ lucri, dissolutumque æs alienum. . . . Postea, Annibale urgente, Q. Fabio Maximo Dictatore, asses unciales facti: placuitque denarium xvi. assibus permutari, quinarium octonis, sestertium quaternis. Ita resp. dimidium lucrata est. Mox lege Papyria semunciales asses facti." (Plinii, *Hist. Nat.* lib. xxxij, cap. 3. Lugd. Bat. 1669.)

³ This is, indeed, decisively proved by a passage in Celsus: "Sed et antea sciri volo in uncia pondus denariorum esse septem." (Cels. lib. xv. cap. 17.)

⁴ Greaves, vol. i. p. 331. Gibbon's *Miscellaneous Works*, vol. v. p. 71.

Money. Christ. The aureus originally weighed $\frac{1}{60}$ th part of the *pondo* or Roman pound; but by successive reductions its weight was reduced, in the reign of Constantine, to only $\frac{1}{12}$ th part of a pound. The purity, however, as well as the weight of the aureus was diminished. Under Alexander Severus it was alloyed with $\frac{1}{3}$ th part of silver. We learn from Dion Cassius, contemporary with Severus, that the aureus was rated at twenty-five denarii, a proportion which Mr. Pinkerton thinks was always maintained under the emperors. (*Essay on Medals*, vol. i. p. 148.)

Value of the sestertius. The want of attention to this progressive degradation has led the translators of, and commentators on, ancient writers, to the most extraordinary conclusions. The sestertius, or money unit of the Romans, was precisely the *fourth* part of a denarius. "Nostri autem," says Vitruvius, (lib. iii. cap. 1,) "primo decem fecerunt antiquum numerum, et in denario denos æreos asses constituerunt, et ea re compositio nummi ad hodiernum diem denarii nomen retinet; etiamque quartam ejus partem, quod efficiebatur ex duobus assibus et tertio semisse *sestertium* nominaverunt." When, therefore, the denarius was worth 8 $\frac{1}{2}$ d., the sestertius must have been worth 2 $\frac{1}{4}$ d. But the sestertius being thus plainly a multiple of, and bearing a fixed and determined proportion to the denarius, and consequently to the as, the aureus, and the other coins generally in use, it must have partaken of all their fluctuations. When they were reduced, the sestertius must have been likewise reduced; for if it had not been so reduced, or, if the quantity of degraded denarii and aurei contained in a given sum of sestertii had been increased in proportion to their degradation, nothing, it is obvious, would have been gained by falsifying the standard. But as we know that on one occasion the republic got rid of half of its debts, *res publica dimidium lucrata est*, by simply reducing the standard of the as, it is certain that the value of the sestertius must have fallen in the same proportion, just as in England we should reduce the pound sterling, our money unit, by reducing the shillings of which it is made up.¹

Errors of Dr Arbuthnot and others. But though it had not been possible to produce such clear and explicit evidence of the continued degradation of the Roman money, the obvious absurdity of many of the calculations which have been framed, on the supposition of its remaining stationary at the rates fixed in the earlier ages of the commonwealth, would have sufficiently established the fact of its degradation. Dr. Arbuthnot's *Tables of Ancient Coins*, which, for nearly a century, have been considered in England, and in the greater part of the Continent, as of the highest authority, are constructed on the hypothesis that the denarii weighed by Mr. Greaves were of equal purity with English standard silver, and that no subsequent diminution had been made either in their weight or fineness. The conclusions derived from such data are precisely such as we should arrive at, if, in estimating the value of a French livre previously to the Revolution, we took for granted that it weighed a pound of pure silver, as in the reign of Charlemagne. Amongst many other things quite as extraordinary, we learn from Arbuthnot, that Julius Cæsar, when he set out for Spain, after his prætorship, was £2,018,229 sterling worse than nothing; that Augustus received, in legacies

from his friends, £32,291,666; that the estate of Pallas, a freedman of Crassus, was worth £2,421,875, and, which is still better, that he received £121,093 as a reward for his virtues and frugality; that Æsop, the tragedian, had a dish served up at his table which cost £4,843; that Vitellius spent £7,265,625 in twelve months, in eating and drinking; and that Vespasian, at his accession to the empire, declared that an annual revenue of £322,916,666 would be necessary to keep the state machine in motion. It is astonishing that none of our scholars or commentators seem ever to have been struck with the palpable extravagance of such conclusions, which, to use the words of Garnier, "ont mis l'Histoire Ancienne, sous le rapport des valeurs, au même degré de vraisemblance que les contes de *Mille et un Nuits*." They have, we believe, without any exception, slavishly copied the errors of Arbuthnot; and to this hour the computations in the books on Roman antiquities used in our schools and universities are all borrowed from his work. It should be remembered, that from the greater poverty of the mines of the old world, and the comparatively small progress made by the ancients in the art of mining, the value of gold and silver was much greater in ancient times than at present. But, without taking this circumstance into account, the computations referred to are too obviously erroneous to deserve the smallest attention. Vespasian, we believe, would have been very well satisfied with a revenue of twenty millions; and there are good grounds for supposing that the Roman revenue, when at the highest, never amounted to so large a sum. (Gibbon, vol. i. p. 260.)

FRENCH MONEY.—From about the year 800, in the reign of Charlemagne, to the year 1103, in that of Philip I., the French *livre*, or money unit, contained exactly a pound weight or twelve ounces (poids de marc) of pure silver. It was divided into twenty sols, each of which, of course, weighed $\frac{1}{20}$ th part of a pound. This ancient standard was first violated by Philip I., who diminished considerably the quantity of pure silver contained in the sols. The example once set, was so well followed up, that in 1180 the livre was reduced to less than a *fourth* part of its original weight of pure silver. In almost every succeeding reign there was a fresh diminution. "La monnoye," says Le Blanc, "qui est la plus précieuse et la plus importante des mesures, a changé en France presque aussi souvent que nos habits ont changé de mode." And to such an extent had the process of degradation been carried, that, at the epoch of the Revolution, the livre did not contain a *seventy-eighth* part of the silver contained in the livre of Charlemagne. It would then have required 7,885 livres really to extinguish a debt of 100 livres contracted in the ninth or tenth centuries; and an individual who, in that remote period, had an annual income of 1,000 livres, was as rich, in respect to money, as those who, at the Revolution, enjoyed a revenue of 78,850 livres. (Paucton, *Traité des Mesures, Poids, &c.*, p. 693.)

We subjoin an abridged table, calculated by M. Denis, exhibiting the average value of the French livre in different periods, from the year 800 to the Revolution:—

¹ Writers on ancient coins, with the exception of Mr. Pinkerton, agree in supposing the sestertius to have been originally, and to have always continued to be, a silver coin. Mr. Pinkerton has, however, denied this opinion, and, on the authority of the following passage of Pliny, contends that the sestertius was at the time when Pliny wrote, whatever it might have been before, a brass coin. "Summa gloria æris nunc in Marianum conversa, quod et Cordubense dicitur. Hoc a Liviano cadmiam maxime sorbet, et orichalci bonitatem imitatur in SESTERTIIS, DUPONDIARIISQUE, Cyprio suo ASSIBUS contentis." (Lib. xxxiv. cap. 2.) That is, literally, "The greatest glory of brass is now due to the Marian, also called that of Cordova. This, after the Livian, absorbs the greatest quantity of lapis calaminaris, and imitates the goodness of orichalcum (yellow brass) in our SESTERTII and DUPONDIARI, the ASSES being contented with the Cyprian (brass)." [Pliny had previously observed, that the Cyprian was the least valuable brass]. This passage is, we think, decisive in favour of Mr. Pinkerton's hypothesis. But, in the absence of positive testimony, the small value of the sestertius might be relied on as a sufficient proof that it could not be silver. When the denarius weighed 62 grains, the sestertius must have weighed 15 $\frac{1}{2}$, and been worth 2 $\frac{1}{4}$ d.; but a coin of so small a size as to be scarcely equal to one-third part of one of our sixpences, would have been extremely apt to be lost; and could not have been struck by the rude methods used in the Roman mint with any thing approaching to even tolerable precision. It is, therefore, much more reasonable to suppose that it was of brass.

Money.

Money.

Reigns.	Years.	Value of the Livre in the cur- rent money of 1789.
		Liv. Sols. Den.
From the 32d year of Charlemagne to the 43d year of Philip I.,or from	800 to 1103	78 17 0
Part of the reign of Philip I., Louis VI., and VII.... —	1103 — 1180	18 13 8
Philip II. and Louis VIII..... —	1180 — 1226	19 18 4½
Louis IX. and Philip IV..... —	1226 — 1314	18 3 5
Louis X. and Philip V..... —	1314 — 1322	17 3 5
Charles IV. and Philip VI..... —	1322 — 1350	14 11 10
John, —	1350 — 1364	9 19 2½
Charles V..... —	1364 — 1380	9 9 8
Charles VI..... —	1380 — 1422	7 2 3
Charles VII..... —	1422 — 1461	5 13 9
Louis XI..... —	1461 — 1483	4 19 7
Charles VIII..... —	1483 — 1498	4 10 7
Louis XII..... —	1498 — 1515	3 19 8
Francis I..... —	1515 — 1547	3 11 2
Henry II and Francis II..... —	1547 — 1560	3 6 4½
Charles IX..... —	1560 — 1574	2 18 7
Henry III..... —	1574 — 1589	2 12 11
Henry IV..... —	1589 — 1610	2 8 0
Louis XIII..... —	1610 — 1643	1 15 3
Louis XIV..... —	1643 — 1715	1 4 11
Louis XV..... —	1715 — 1720	0 8 0
Louis XV. and XVI..... —	1720 — 1789	1 0 0

Those who wish for a detailed account of the various changes in the weight and purity of the French coins, may besides the excellent work of Le Blanc, consult the elaborate and very complete tables at page 905 of the *Traité des Mesures* of Paucton, and at page 197 of the *Essai sur les Monnoies* of Dupré de St. Maur.

It was not to be expected, that degradations originating in the necessities, the ignorance, and the rapacity of a long series of arbitrary princes, should be made according to any fixed principle. They were sometimes the result of an increase in the denomination of the coins, but more frequently of a diminution of the purity of the metal of which they were struck. A degradation of this kind was not so easily detected; and, in order to render its discovery still more difficult, Philip of Valois, John, and some other kings, obliged the officers of the mint to swear to conceal the fraud, and to endeavour to make the merchants believe that the coins were of full value. (Le Blanc, p. 212.) Sometimes one species of money was reduced, without any alteration being made in the others. No sooner, however, had the people in their dealings manifested a preference, as they uniformly did, for the money which had not been reduced, than its circulation was forbidden, or its value brought down to the same level with the rest. (Id. *Introduction*, p. 20.) In order to render the subject more obscure, and the better to conceal their incessant frauds, individuals were at one time compelled to reckon exclusively by livres and sols, at other times by crowns or ecus; and not unfrequently they were obliged to refer in computing to coins which were neither livres, sols, nor crowns, but some multiple or fractional part thereof. The injurious effects of these constant fluctuations in the value of money are forcibly depicted by the French historians; and so insupportable did they become, that in the fourteenth and fifteenth centuries, several cities and provinces were glad to purchase the precarious and little respected privilege of having coins of a fixed standard, by submitting to the imposition of heavy taxes. (Le Blanc, p. 93.)

In the duchy of Normandy, when it was governed by the English monarchs, there was a tax upon hearths paid every three years, called *monetagium*, in return for which the sovereign engaged *not to debase his coins*. This tax was in-

troduced into England by our early kings of the Norman race; but Henry I. in the first year of his reign, was induced to abandon it, and it has not since been revived. (Liverpool on Coins, p. 107.)

According to the present regulations of the French mint, the coins contain $\frac{9}{10}$ ths of pure metal, and $\frac{1}{10}$ of alloy. The *franc*, which is equal to 1 livre, 0 sols, 3 deniers, weighs exactly 5 grammes, or 77.2205 English Troy grains. The gold piece of 20 francs weighs 102.96 English grains. (Peuchet, *Statistique Elémentaire de la France*, p. 538.)

ENGLISH MONEY.—In England, at the epoch of the Norman conquest, the silver, or money pound, weighed exactly twelve ounces Tower weight. It was divided into twenty shillings, and each shilling into twelve pence, or sterlings. This system of coinage, which is in every respect the same with that established in France by Charlemagne, had been introduced into England previously to the invasion of William the Conqueror, and was continued, without any alteration, till the year 1300, in the 28th Edward I. when it was for the first time violated, and the value of the pound sterling degraded to the extent of $\frac{1}{8}$ per cent. But, the really pernicious effect of this degradation did not consist so much in the trifling extent to which it was carried by Edward, as in the example which it afforded to his less scrupulous successors, by whom the standard was gradually debased, until, in 1601, in the reign of Queen Elizabeth, 62s. were coined out of a *pound* weight of silver. This was a reduction of above *two-thirds* in the standard; so that all the stipulations in contracts, entered into in the reigns immediately subsequent to the Conquest, might, in 1601, and since, be legally discharged by the payment of less than a *third part* of the sums really bargained for. And yet the standard has been less degraded in England than in any other country.

The tables annexed to this article give an ample account of these degradations, and also give the weight of the gold coins, and the proportional value of gold to silver, estimated both by the mint regulations, and by the quantity of fine gold and fine silver contained in the different coins.

SCOTCH MONEY.—In the same manner as the English had derived their system of coinage from the French, the Scotch derived theirs from the English. From 1296 to

Of Eng-
land. De-
gradation of
the pound
sterling.

Money. 1355, the coins of both divisions of the island were of the same size and purity. But, at the last mentioned period, it was attempted to fill up the void occasioned by the remittance of the ransom of David II. to England, by degrading the coins. Till then the money of Scotland had been current in England, upon the same footing as the money of that country; and the preservation of this equality is assigned by Edward III. as a reason for his degrading the English coins. But this equilibrium was soon afterwards destroyed. In the first year of Robert III. (1390), Scotch coin only passed for half its nominal value in England; and, in 1393, Richard II. ordered that its currency, as money, should entirely cease, and that its value should be made to depend on the weight of the genuine metal contained in it. "To close this point at once," says Mr. Pinkerton, "the Scottish money, equal in value to the English till 1355, sunk by degrees, reign after reign, owing to succeeding public calamities, and the consequent impoverishment of the kingdom, till, in 1600, it was only a *twelfth* part of the value of English money of the same denomination, and remained at that point till the union of the kingdoms cancelled the Scottish coinage."—(*Essay on Medals*, vol. ii. p. 99.)

The tables at the end of this article exhibit the successive degradations both of the Scotch silver and gold coins.

At the Union, in 1707, it was ordered that all the silver coins current in Scotland, foreign as well as domestic, except English coins of full weight, should be brought to the Bank of Scotland, to be taken to the mint to be recoinced. In compliance with this order, there were brought in,

Of foreign silver money, (Sterling),	£132,080	17	9
Milled Scottish coins,	96,856	13	0
Coins struck by hammer,	142,180	0	0
English milled coin,	40,000	0	0
Total,	£411,117	10	9

Mr. Ruddiman conjectures, apparently with considerable probability, that the value of the Scotch gold coins, and of the silver coins not brought in, amounted to about as much more. Much suspicion was entertained of the measure of a recoinage; and that large proportion of the people who were hostile to the Union, and did not believe that it would be permanent, brought very little money to the bank. A few only of the hoarded coins have been preserved, the far greater part having either been melted by the goldsmiths, or exported to other countries. (Preface to Anderson's *Diplomata*, p. 176.)

Of Ireland. **IRISH MONEY.**—The gold and silver coins of Great Britain and Ireland are now the same, and have been so for a considerable period. The rate, however, at which these coins used to circulate in Ireland, or their nominal value as money of account, was $8\frac{1}{3}$ per cent. higher than in Great Britain. This difference of valuation, though attended with considerable inconvenience in adjusting the money transactions between the two countries, subsisted from 1689 till 1825 when it was put an end to. For an account of the various species of metallic money which have at different times been current in Ireland, we must refer our readers to Mr. Simons' *Essay on Irish Coins*;¹ a work pronounced by Mr. Ruding to be "the most valuable of all the publications on the coinage of any part of the united empire." (*Annals of the Coinage*, Preface, vol. i. p. 11.)

Of Germany, &c. **MONEY OF GERMANY, SPAIN, &c.**—A similar process of degradation had been universally carried on. "In many parts of Germany, the florin, which is still the integer, or money of account of those countries, was originally a gold

coin, of the value of about 10s. of our present money (old Money. coinage.) It is now become a silver coin, of the value of only 20d.; and its present value, therefore, is only equal to a sixth part of what it was formerly. In Spain, the maravedi, which was in its origin a Moorish coin, and is still the money of account of that kingdom, was in ancient times most frequently made of gold. Le Blanc observes, that, in 1220, the maravedi weighed 84 grains of gold, equal in value to about 14s. (old coinage) of our present money. But this maravedi, though its value is not quite the same in all the provinces of Spain, is now become a small copper coin, equal in general to only $\frac{4}{7}$ of an English penny! In Portugal, the re, or reis, is become of no greater value than $\frac{2}{10}$ of an English penny; it is so small, that in estimating its value in other coins, it is reckoned by hundreds and thousands. The moeda, or moidore, is equal to 4800 reis; and this little coin has now, in fact, no existence but in name. Such has been the fate of all these coins, and such is the present state of their depreciation." (*Liverpool on Coins*, p. 111.)

RUSSIAN MONEY.—The following, according to M. Storch, Of Russia, are the fluctuations in the weight and value of the rouble, or money unit of Russia, since 1700.

Years.	Weight of the Rouble.		Value in Current Roubles of 1821.	
	Zolot.	Dolis.	Rou.	Cop.
1700.....	11	40	2	70 $\frac{1}{2}$
From 1700 to 1718,.....	5	67	1	35
— 1718 — 1731,.....	4	83	1	15 $\frac{1}{2}$
— 1731 — 1762,.....	5	16	1	22 $\frac{1}{2}$
— 1762 — 1821.....	4	21	1	0

The principle of degradation has not, however, been uniformly acted upon. The quantity of bullion contained in the value of coins of the same denomination has sometimes, though rarely, been increased, and creditors enriched at the expense of their debtors. This method of swindling his subjects is said to have been first practised by the profligate Heliogabalus. The Roman citizens being bound to pay into the imperial treasury a certain number of pieces of gold, or *aurei*, the emperor, whose vices have become proverbial, to increase his means of dissipation, without appearing to add to the weight of the taxes, increased the quantity of metal contained in the *aureus*; and thus obtained, by a fraudulent trick, what he might not have obtained by a fair and open proceeding.² In France, the value of the coins has been frequently raised. During the early part of the reign of Philip le Bel, who ascended the throne in 1285, the value of the coin had been reduced to such an extent as to occasion the most violent complaints on the part of the clergy and landholders, and generally of all that portion of the public whose incomes were not increased proportionably to the reduction in the value of money. To appease this discontent, and in compliance with an injunction of the pope, the king at length consented to issue new coins, of the same denomination with those previously current, but which contained about *three* times the quantity of silver. This, however, was merely shifting an oppressive burden from the shoulders of one class to those of another, less able to bear it. The degraded money having been in circulation for about sixteen years, by far the largest pro-

¹ Originally printed at Dublin in 1749, in 4to, and reprinted with some additions in 1810.

² Lamp. *Vita Alex. Severi*, cap. 39.—Perhaps Heliogabalus took the hint from Licinius, a freedman of Julius Cæsar, who, in his government of the Gauls under Augustus, divided the year into fourteen months instead of twelve, because the Gauls paid a certain monthly tribute. Dion Cassius, lib. 72.

MICROMETER.

PLATE CCCLVII.

Fig. 1.

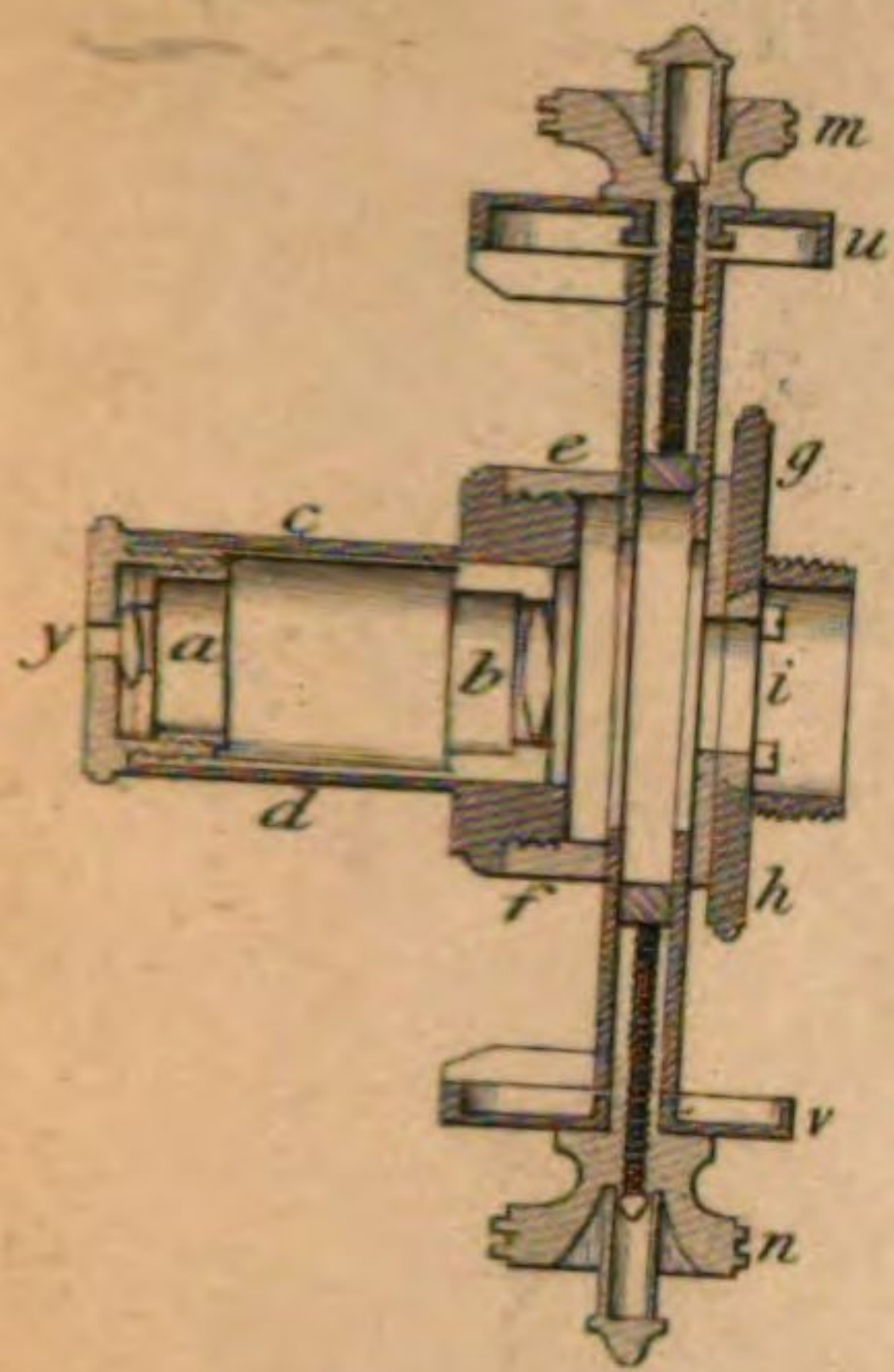


Fig. 2.

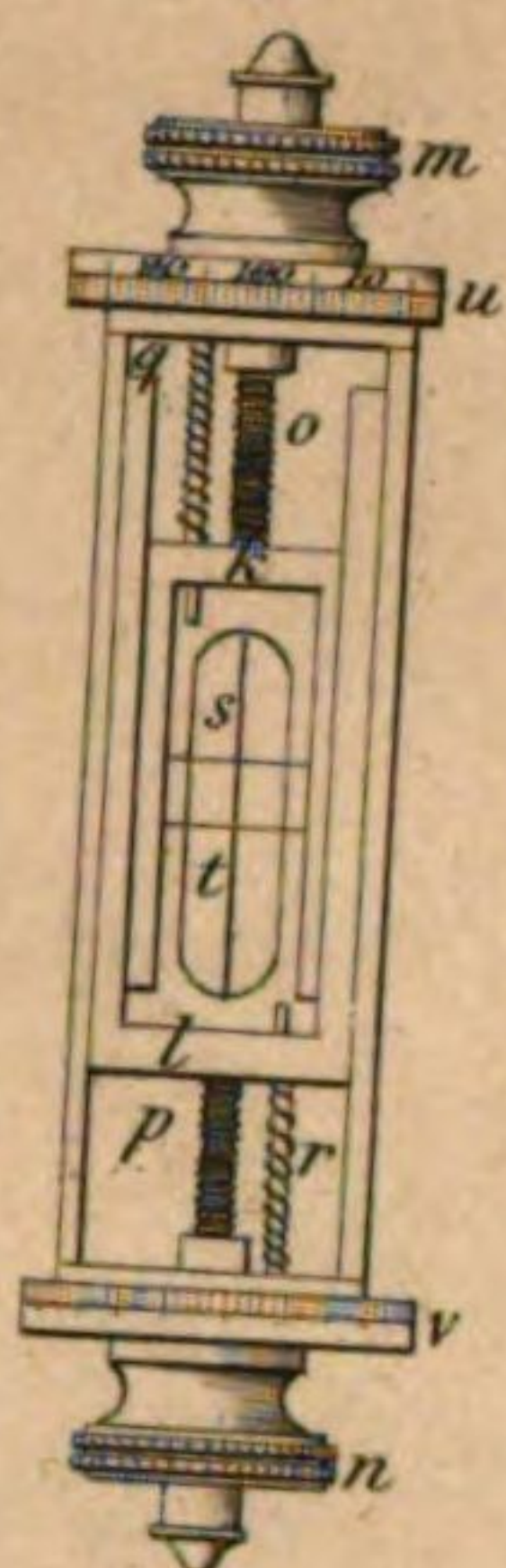


Fig. 3.

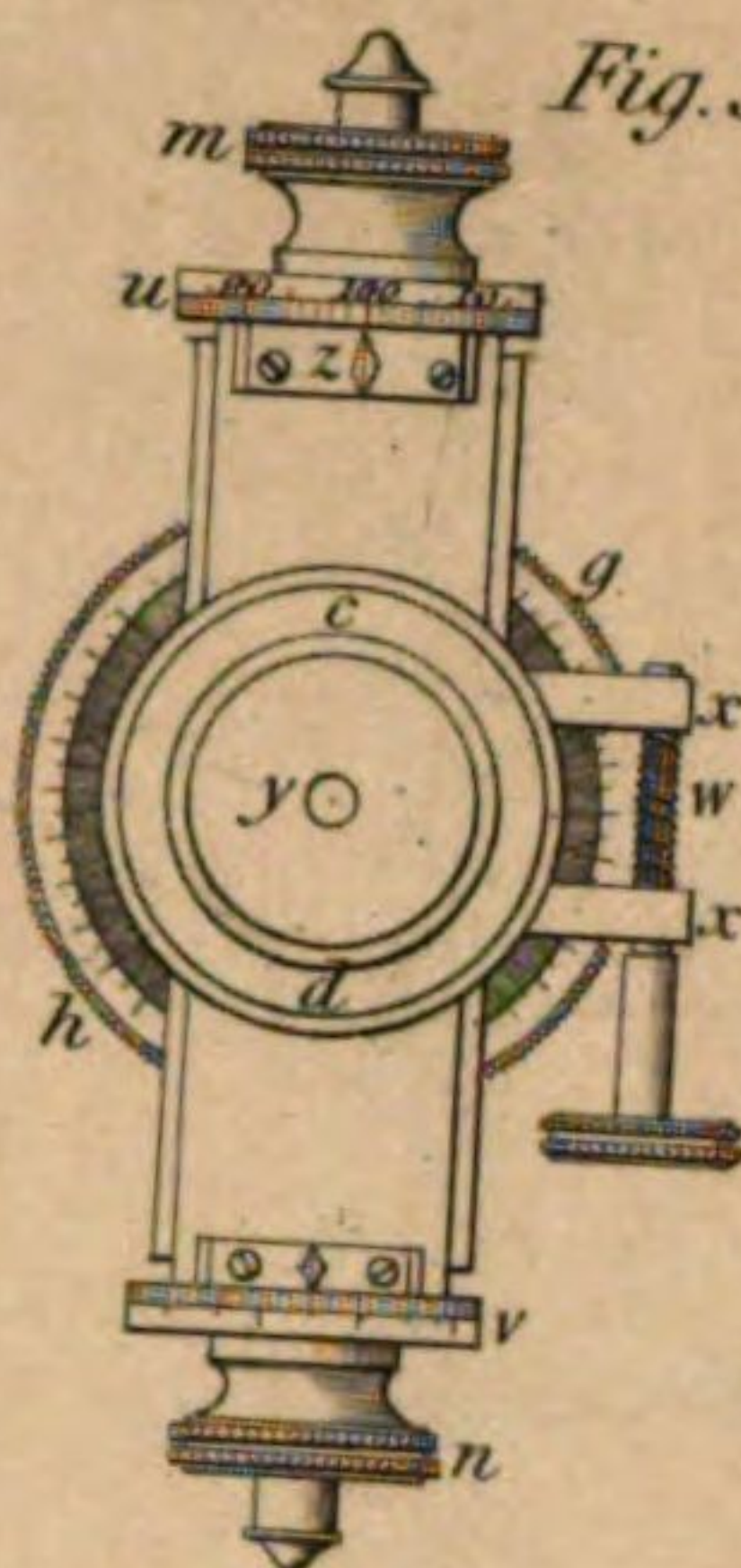


Fig. 5.

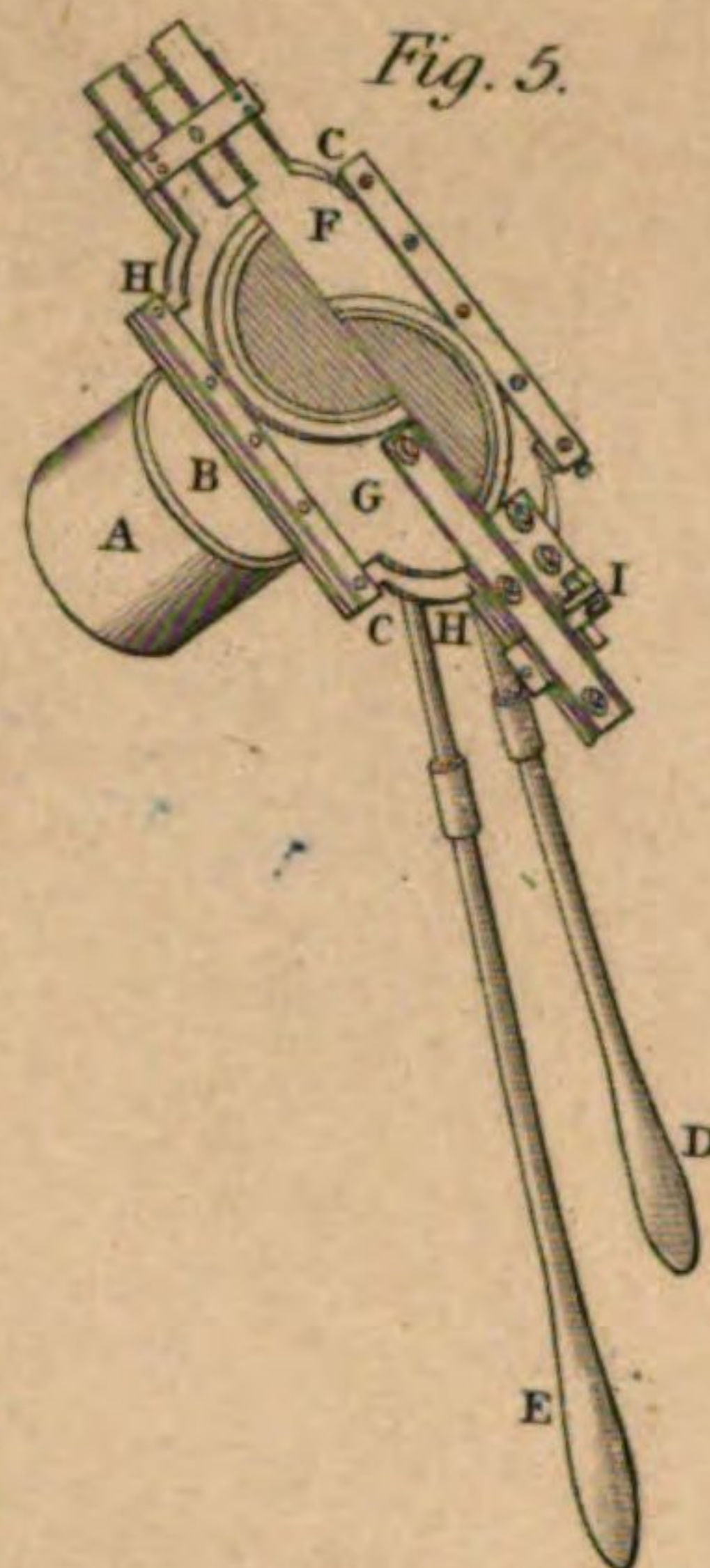


Fig. 9.

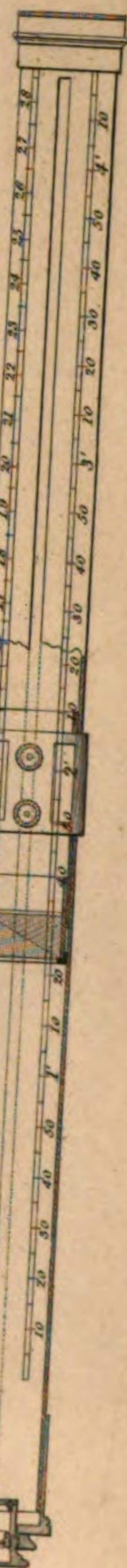


Fig. 4.

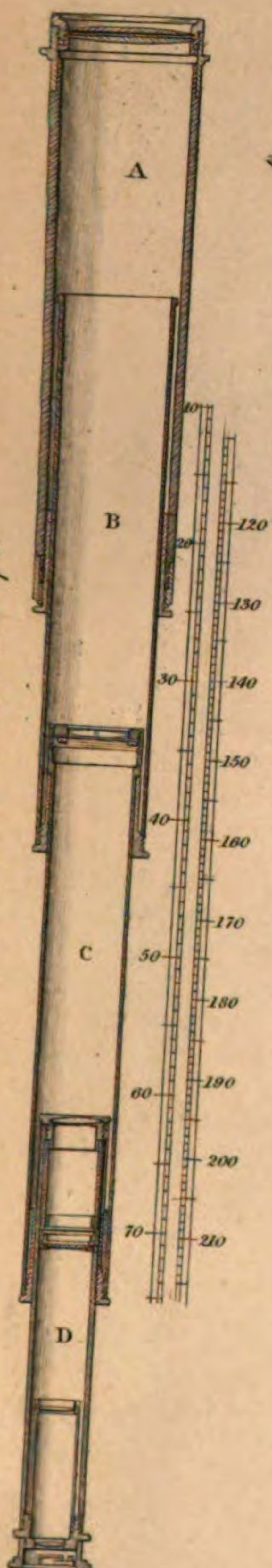


Fig. 7.

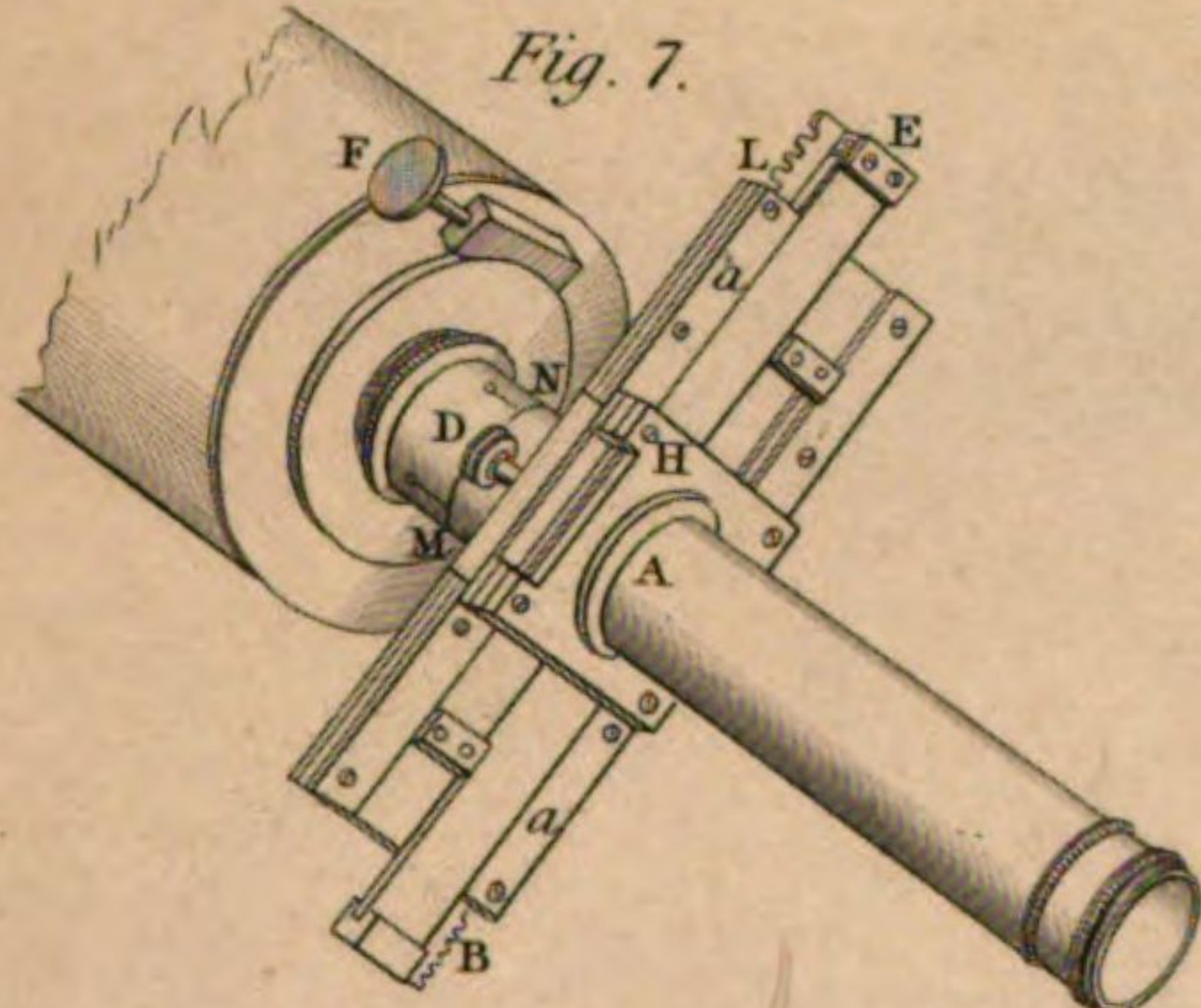


Fig. 6.

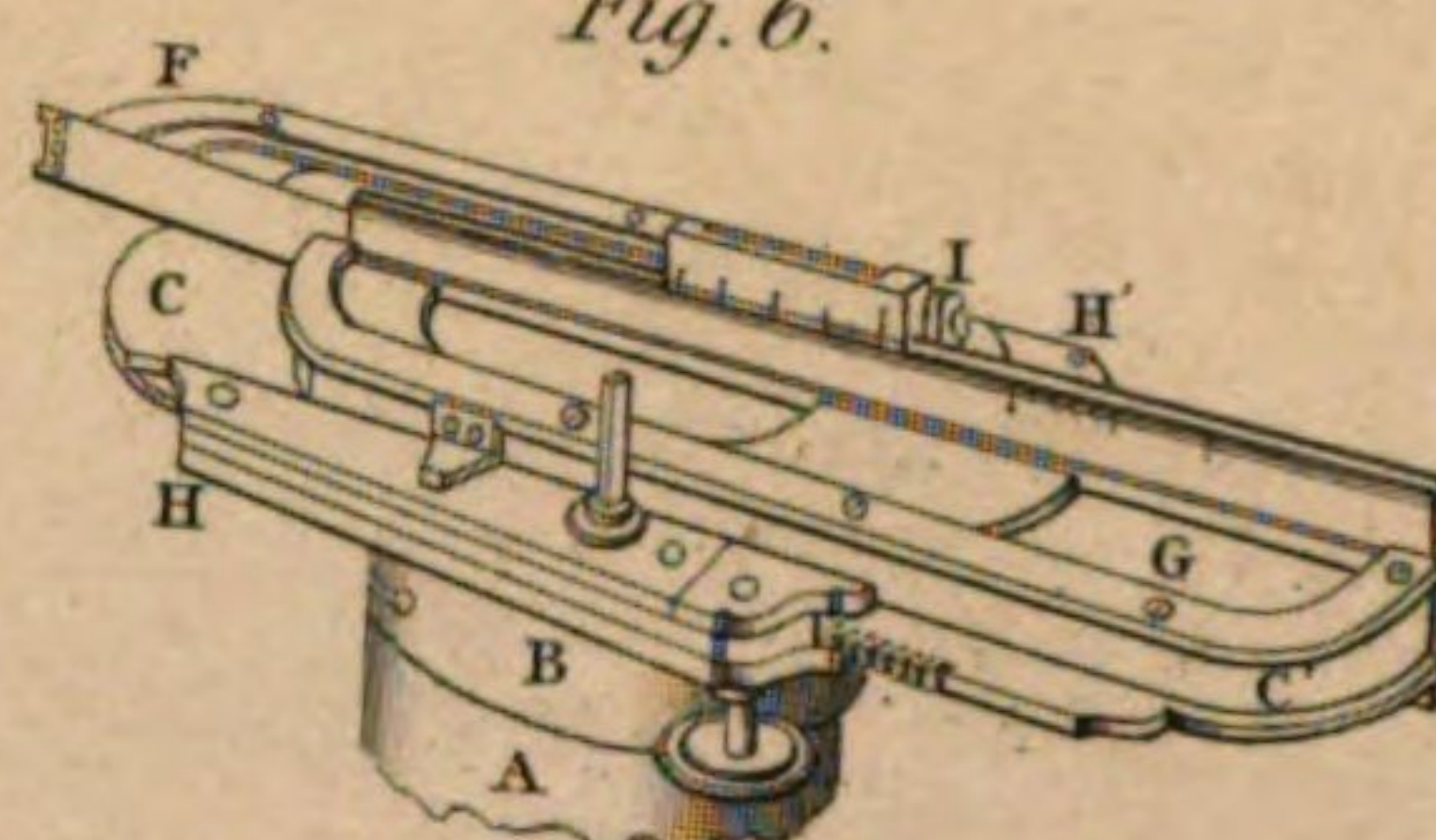


Fig. 10.

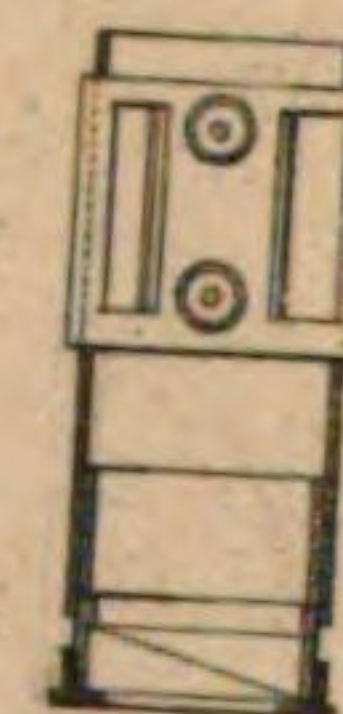


Fig. 8.

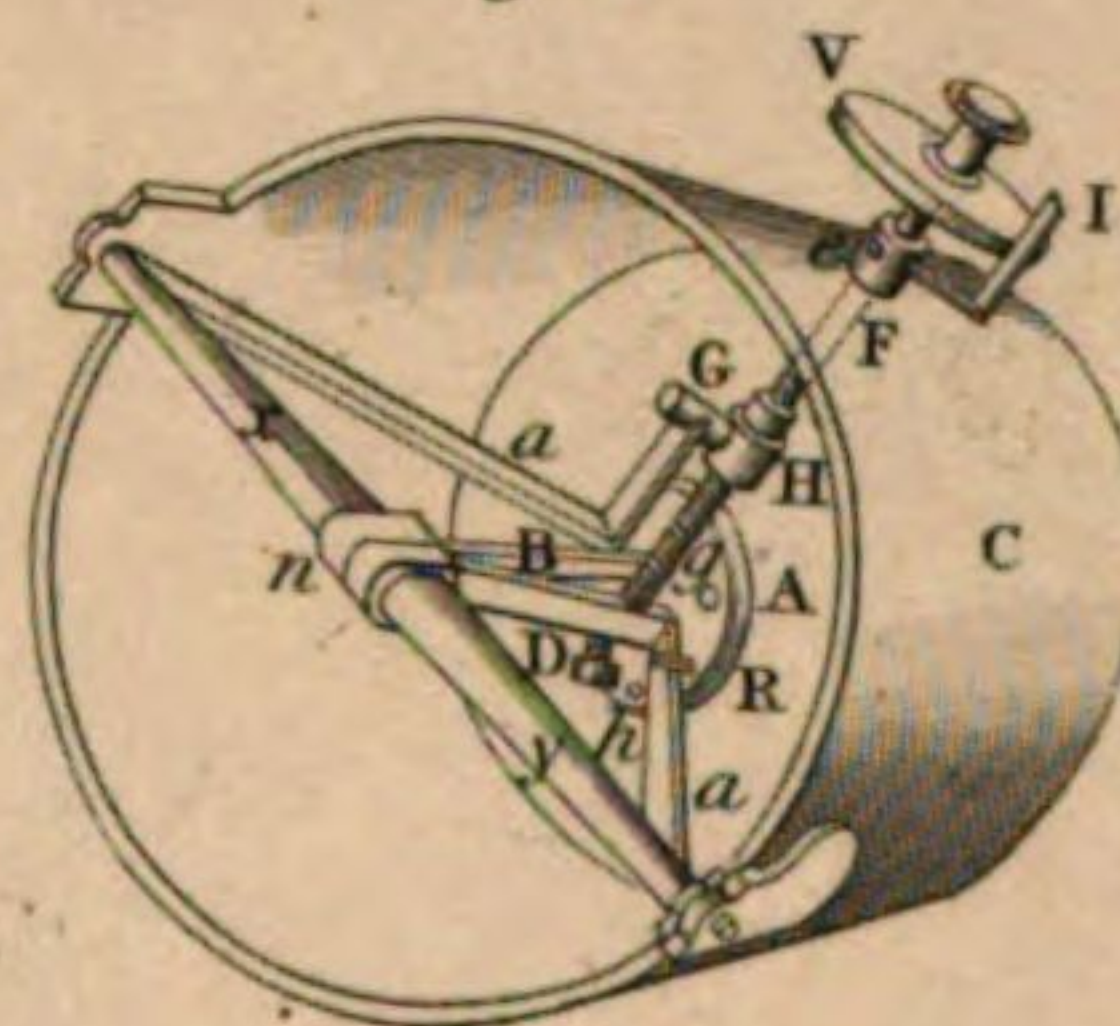


Fig. 11.

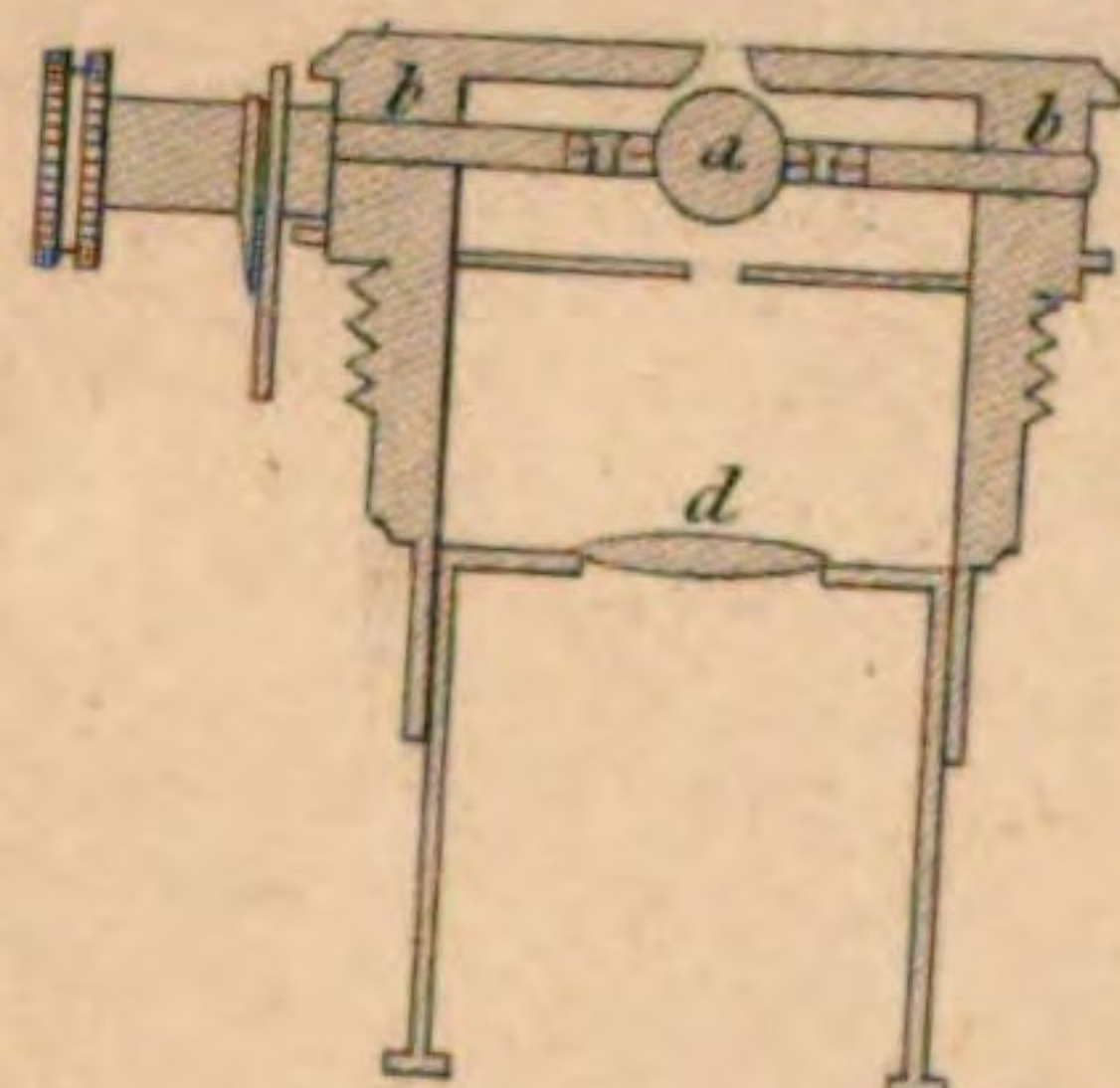


Fig. 14.

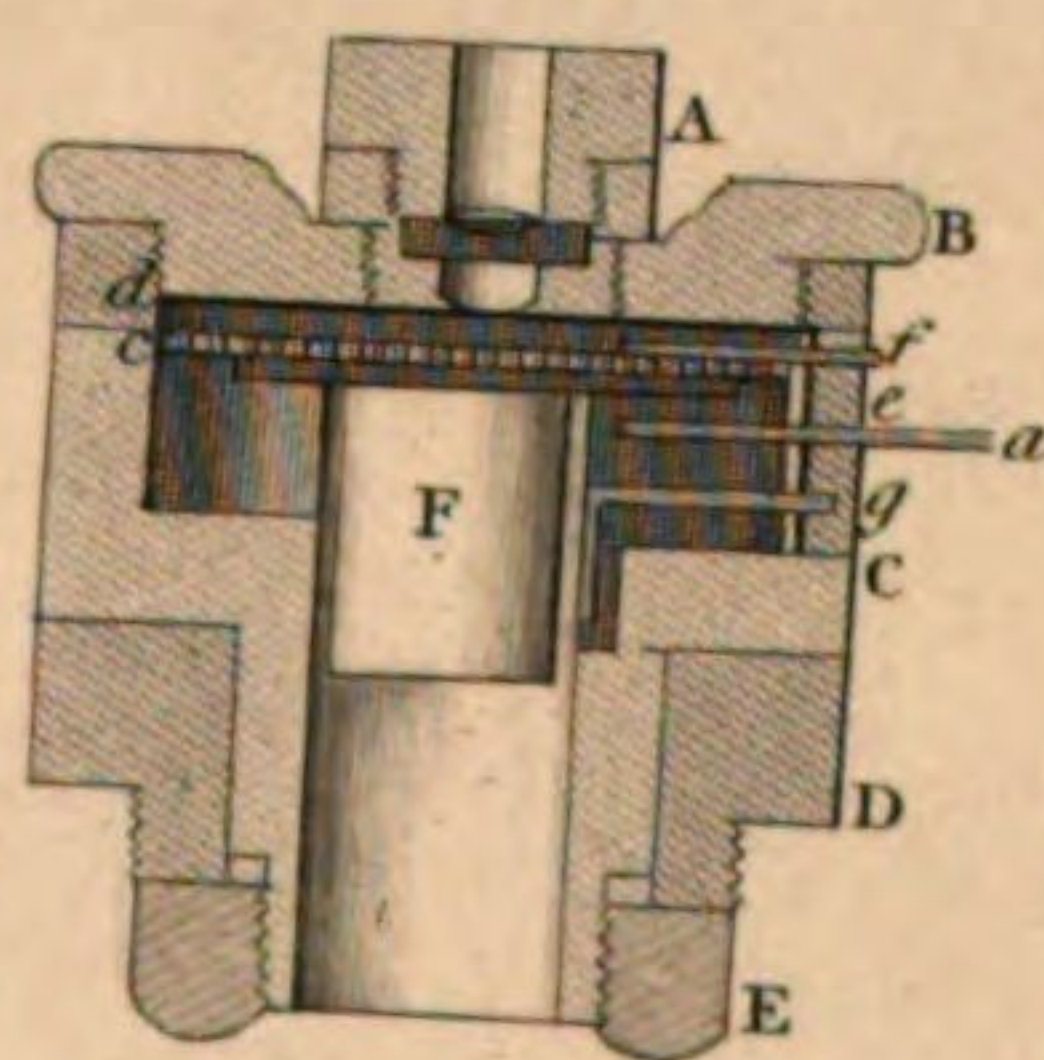


Fig. 15.

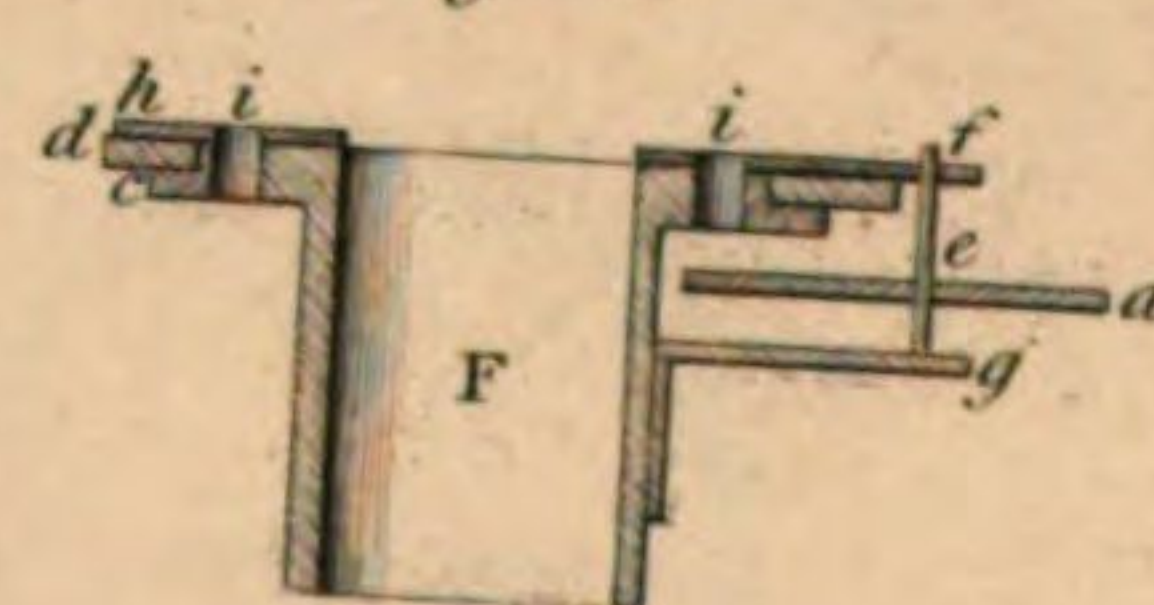


Fig. 12.

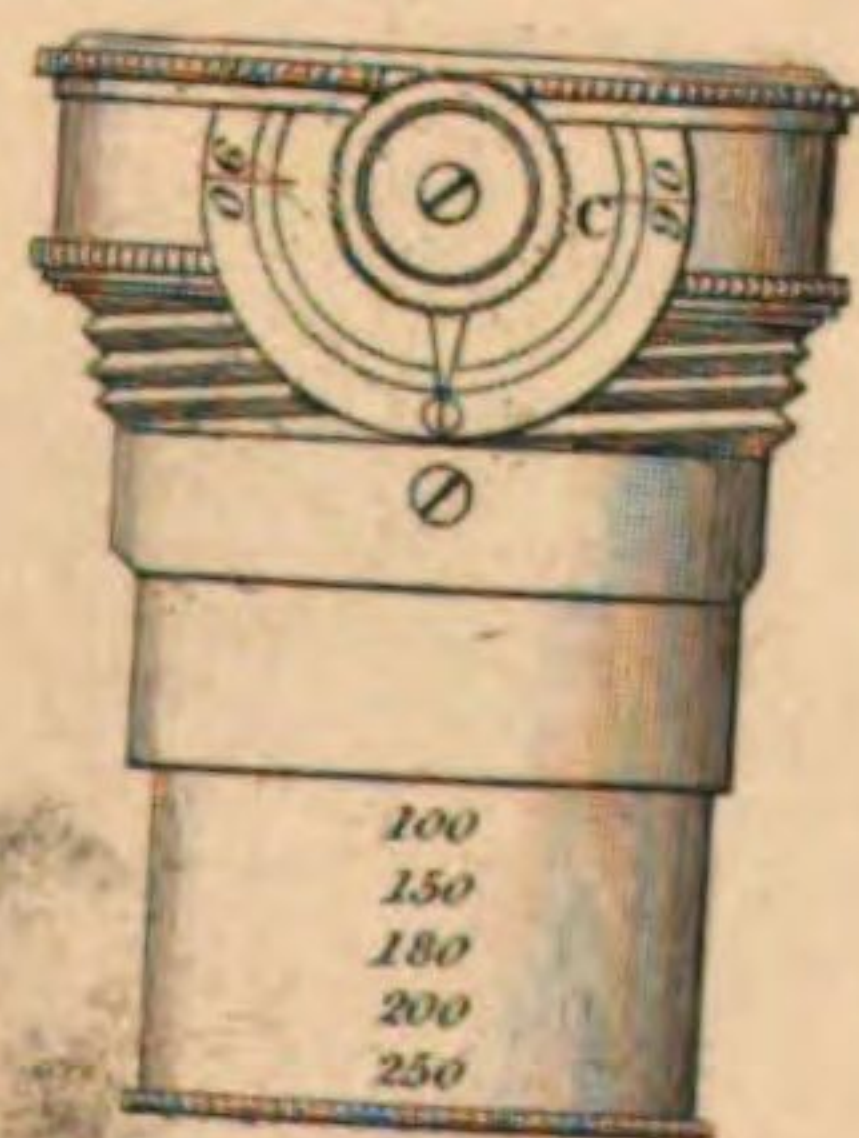


Fig. 13.

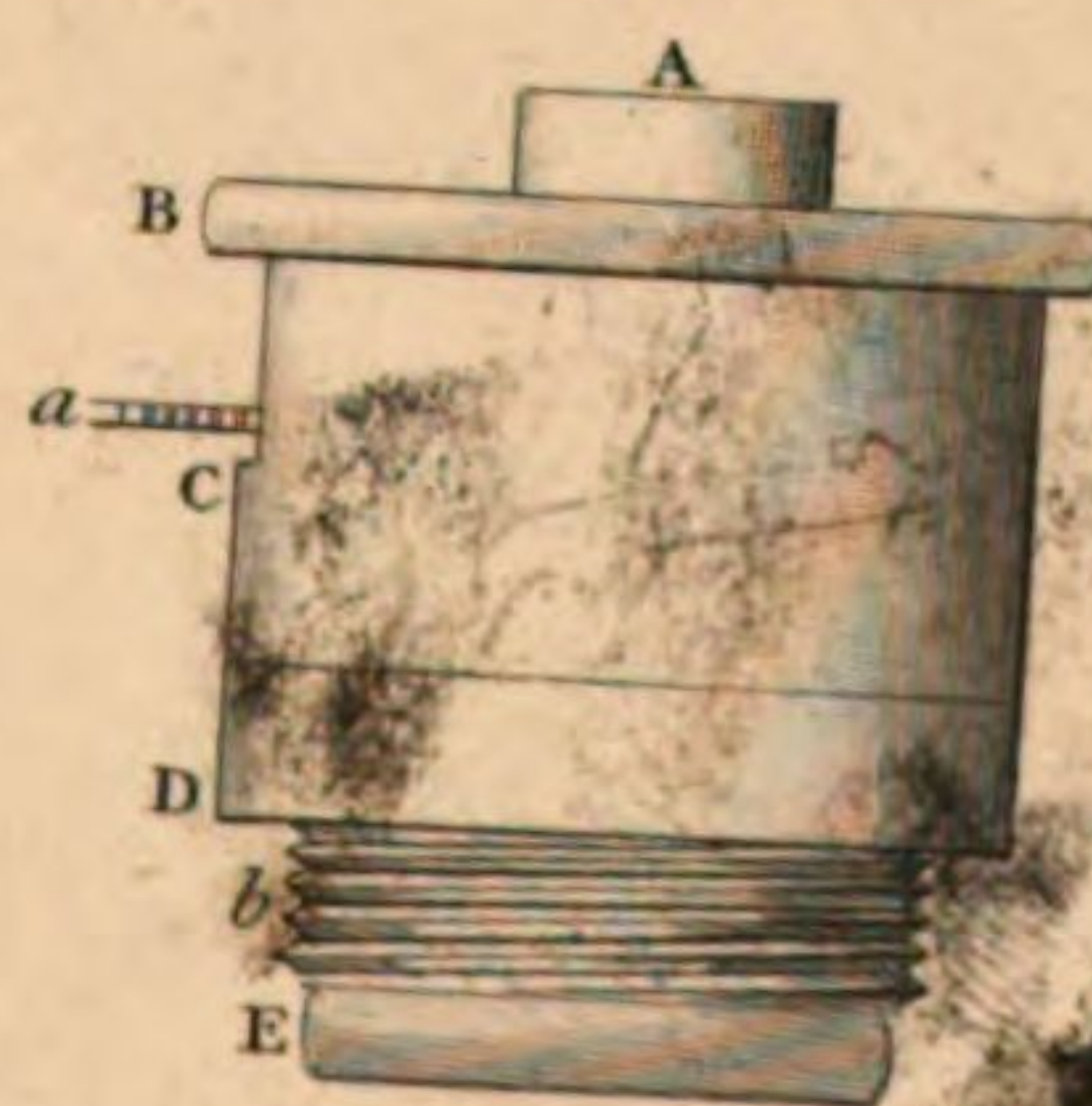
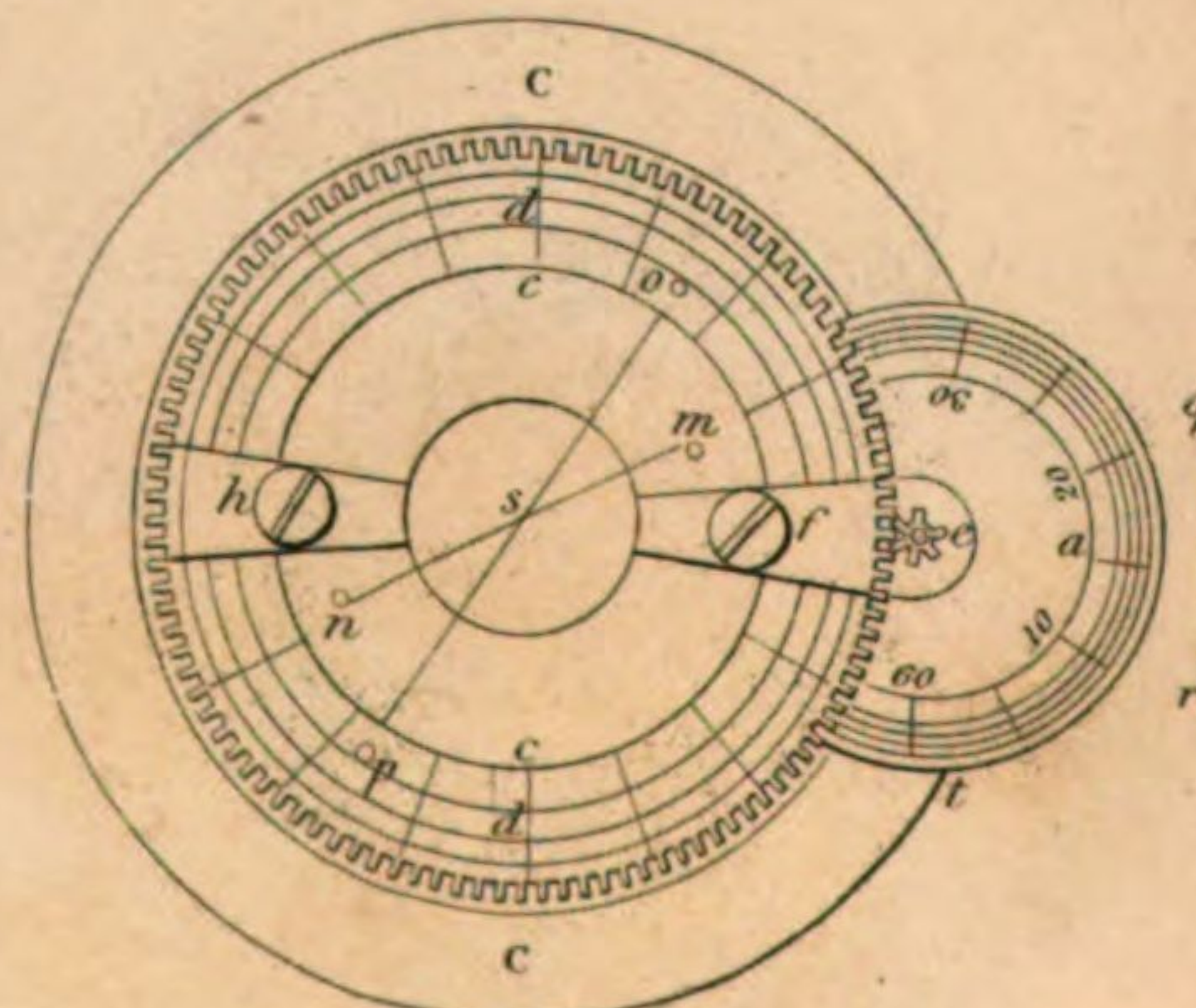
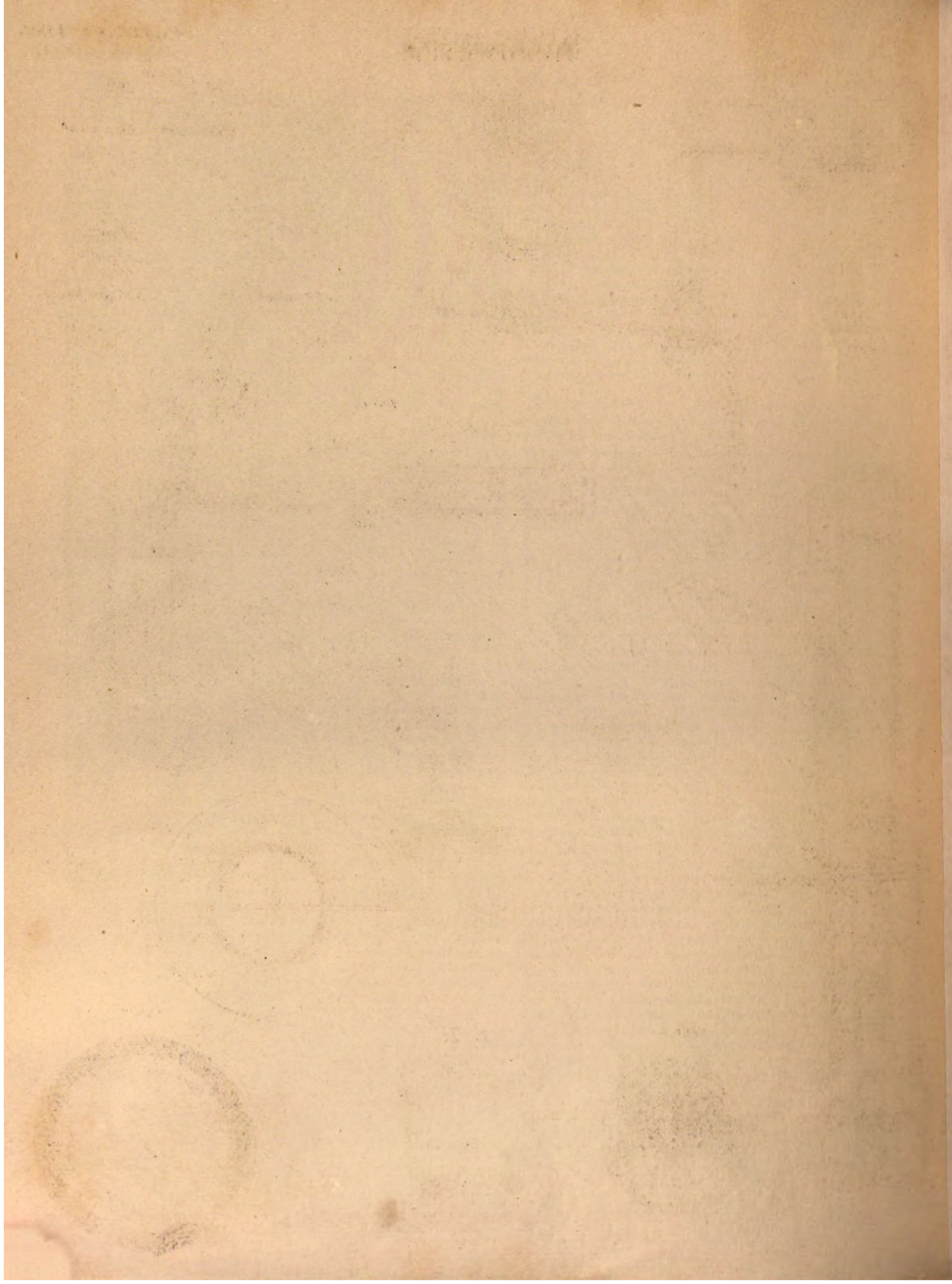


Fig. 16.



Sir D. Brewster's Patent Telescope.



MICROMETER.

PLATE CCCLVIII.

Fig. 17.

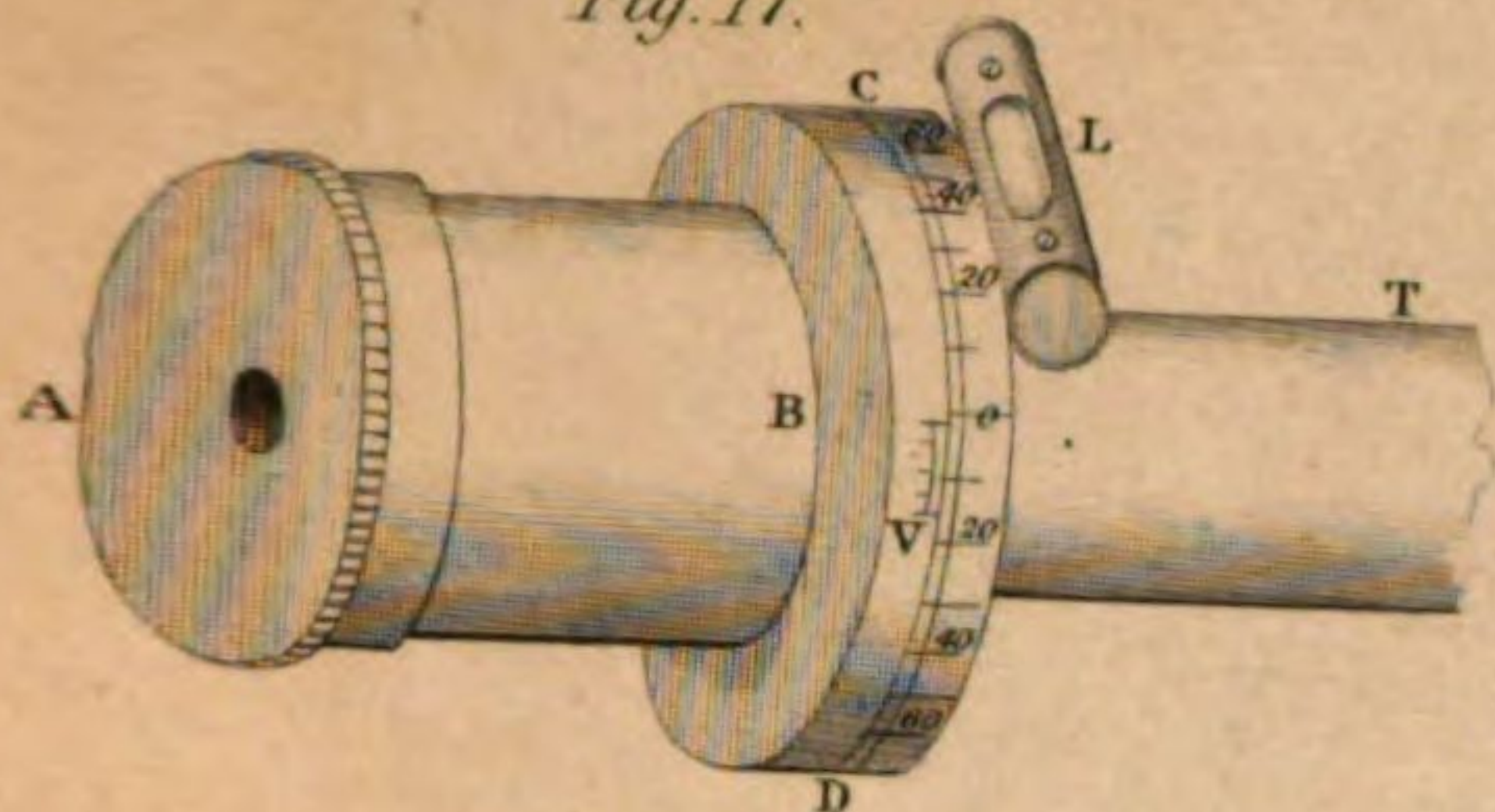


Fig. 18.

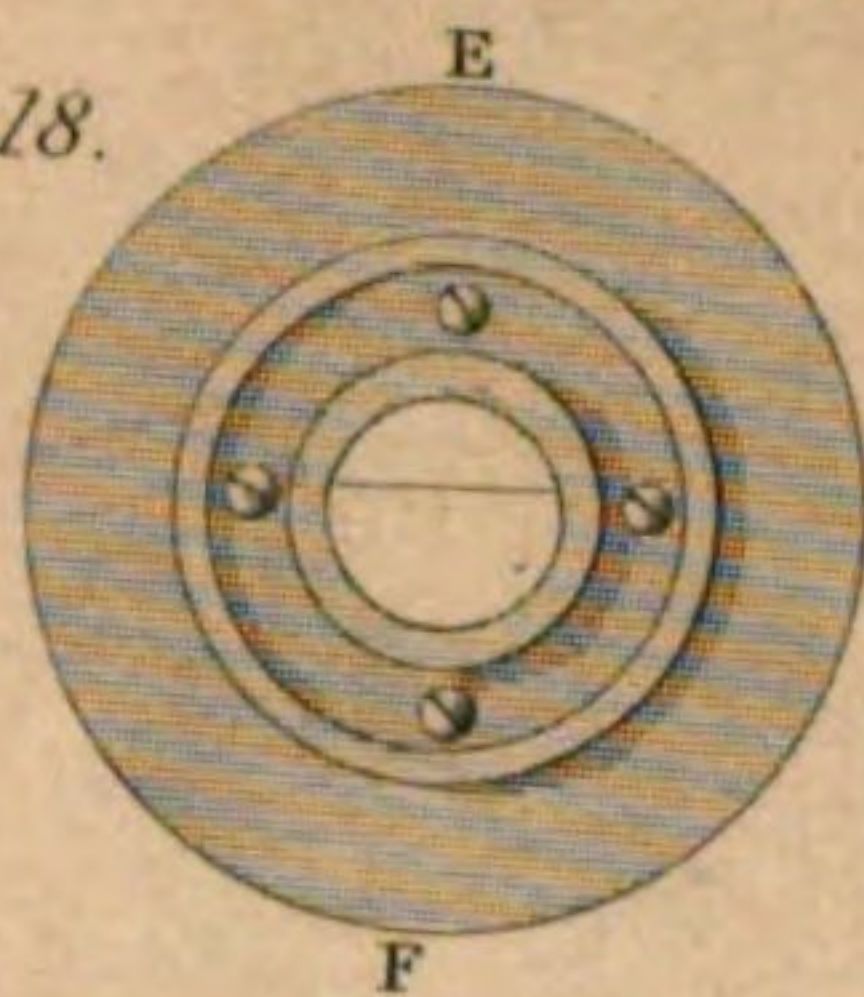


Fig. 19.

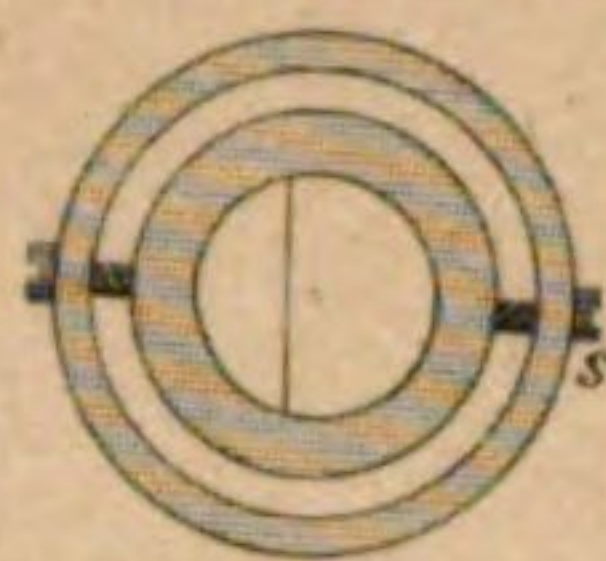


Fig. 20.

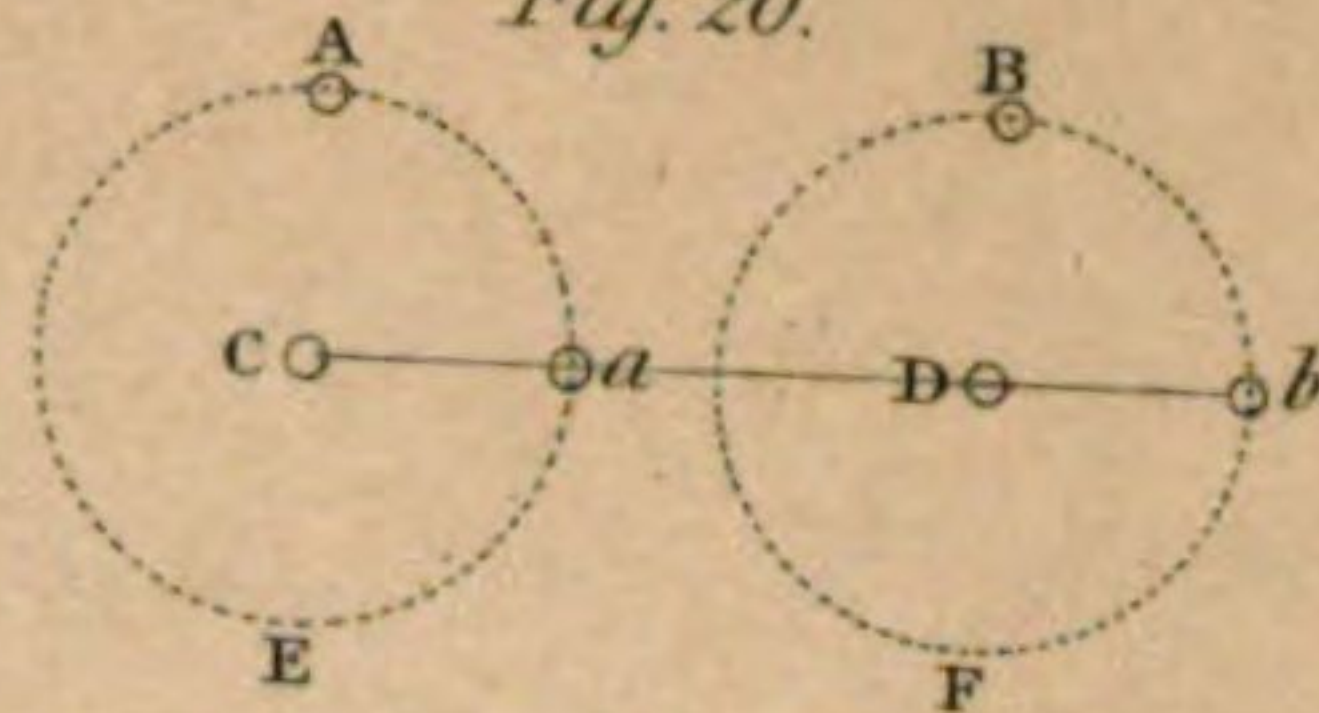


Fig. 24.

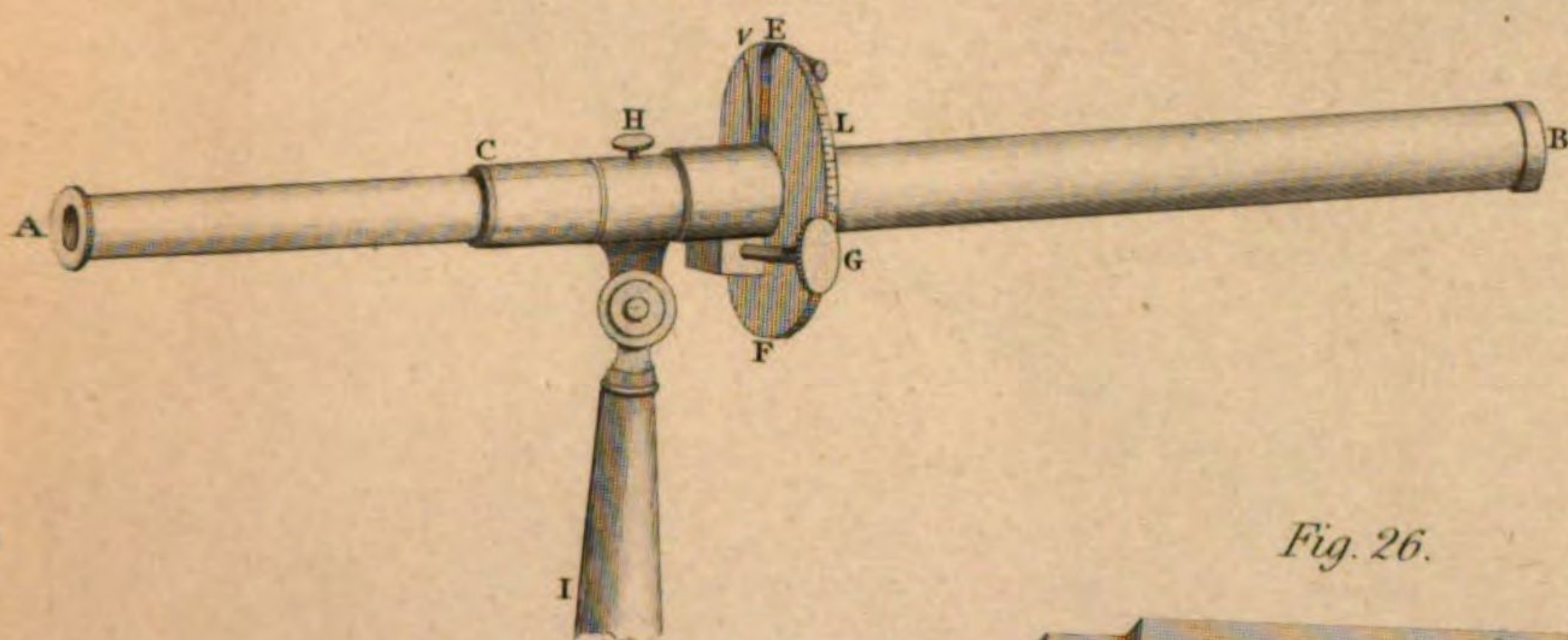


Fig. 21.

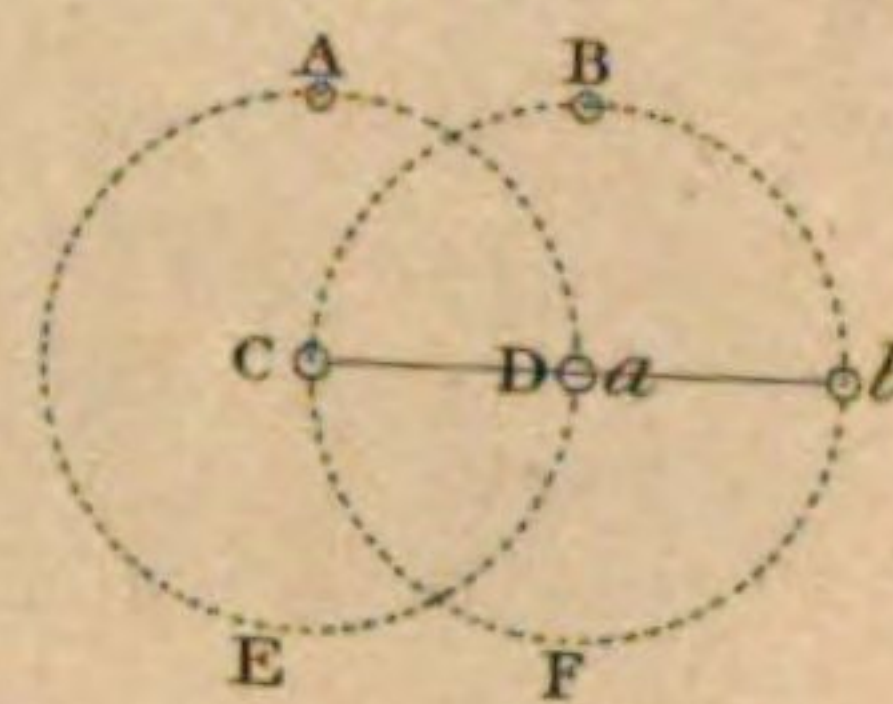


Fig. 22.

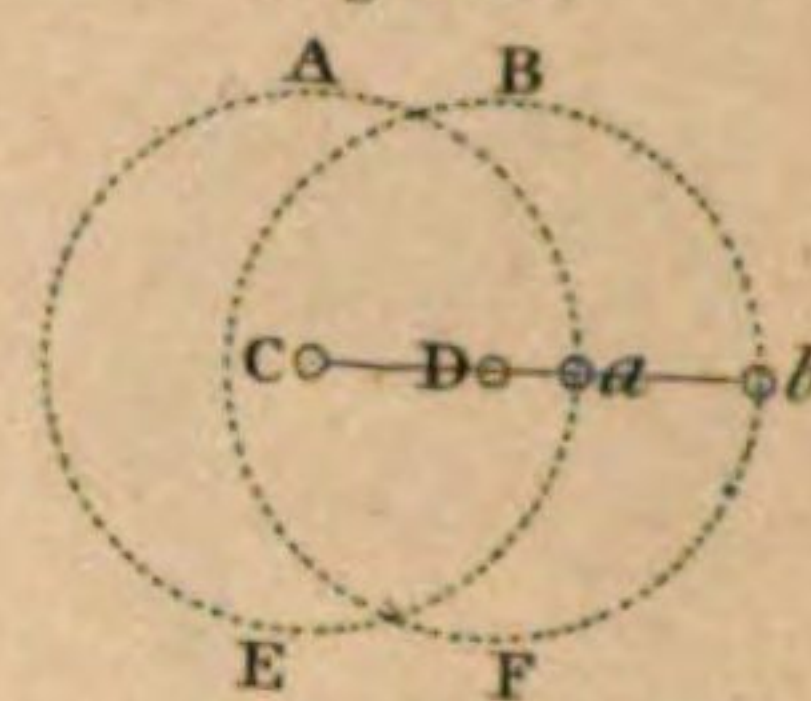


Fig. 23.

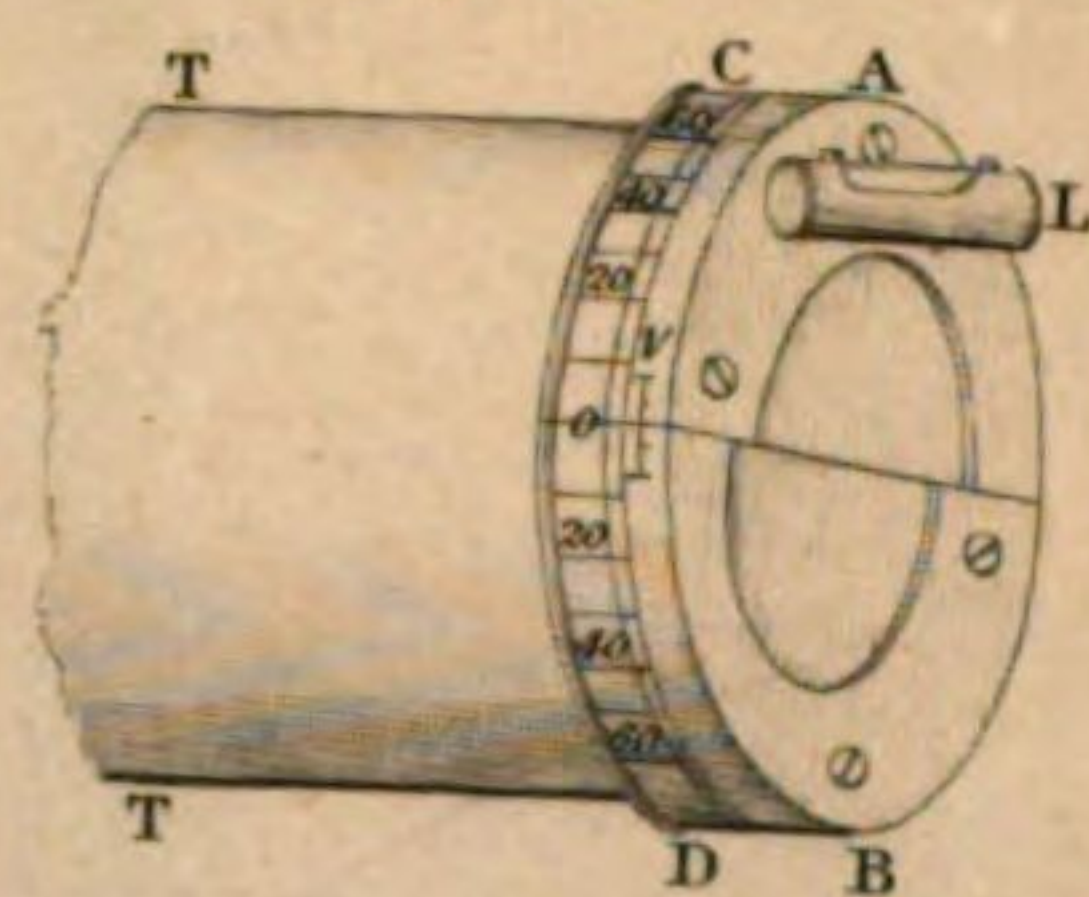


Fig. 26.

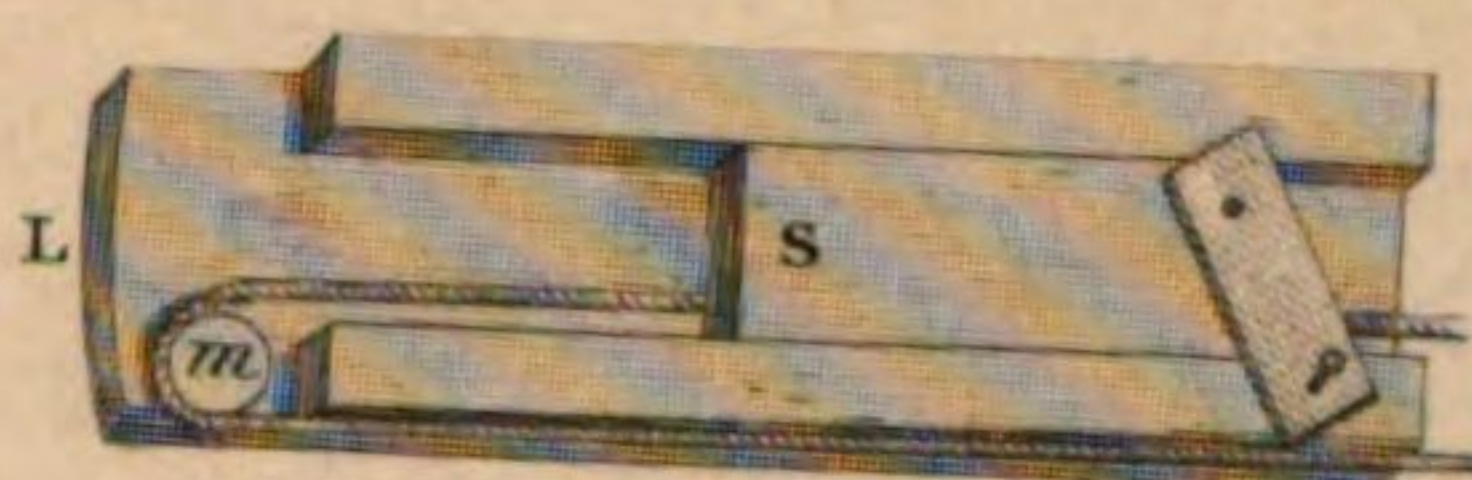


Fig. 25.

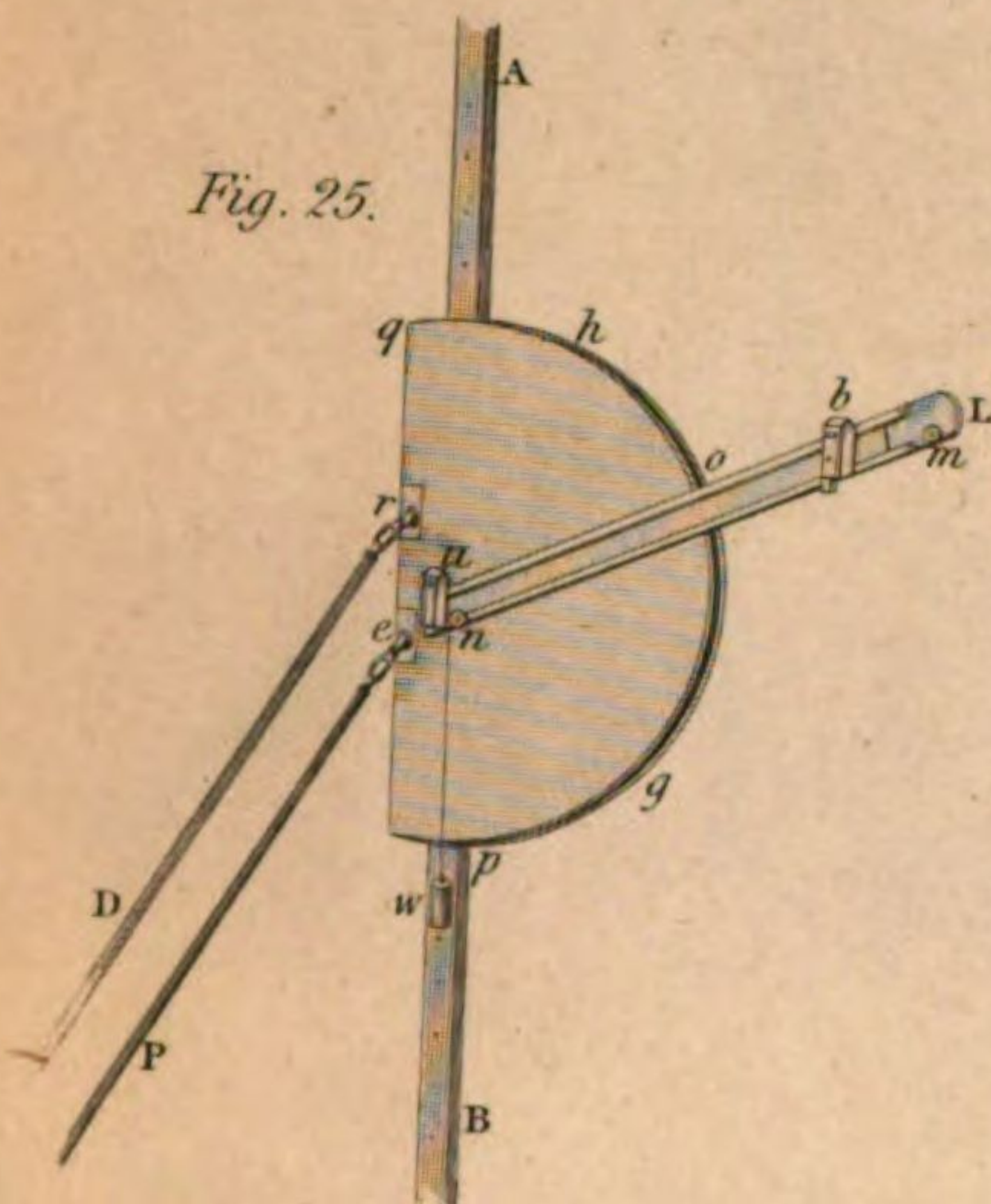


Fig. 27.

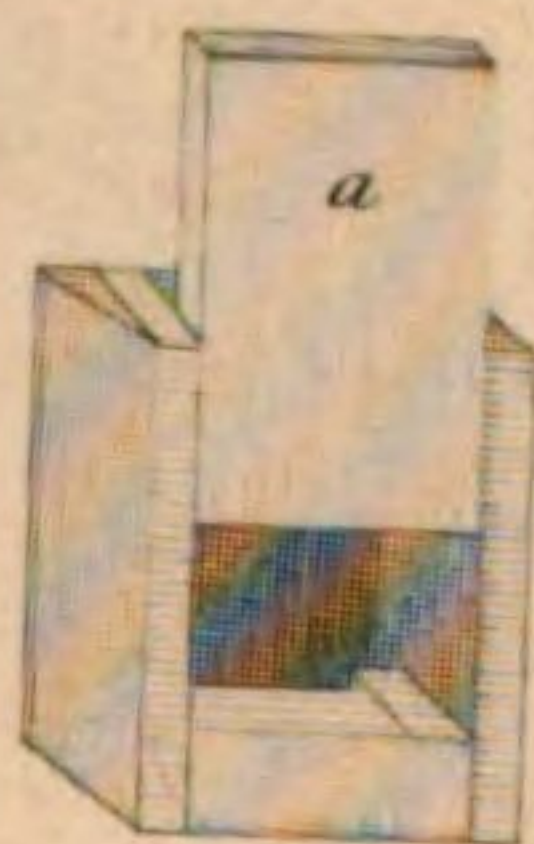


Fig. 28.

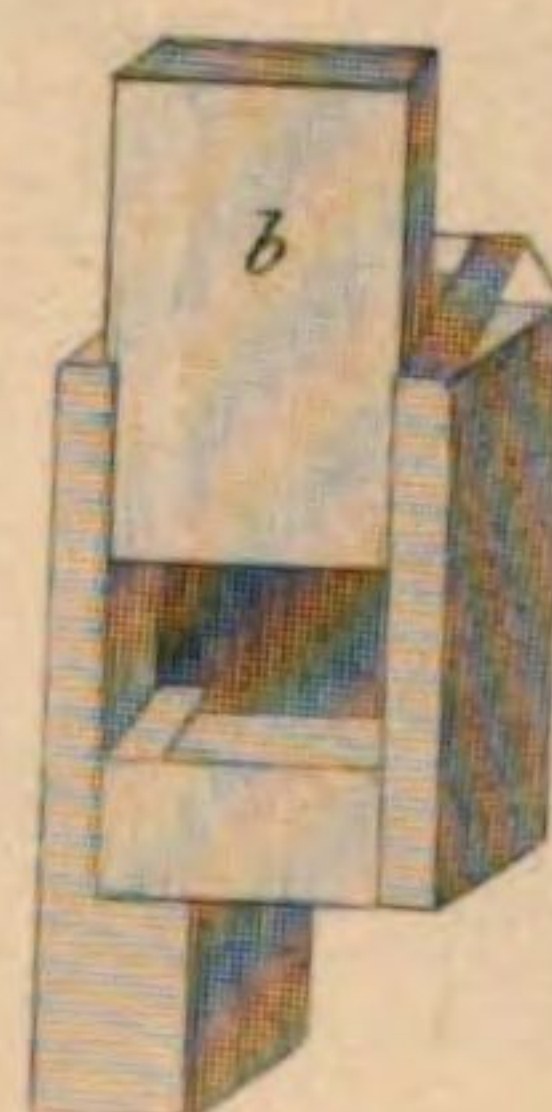


Fig. 29.

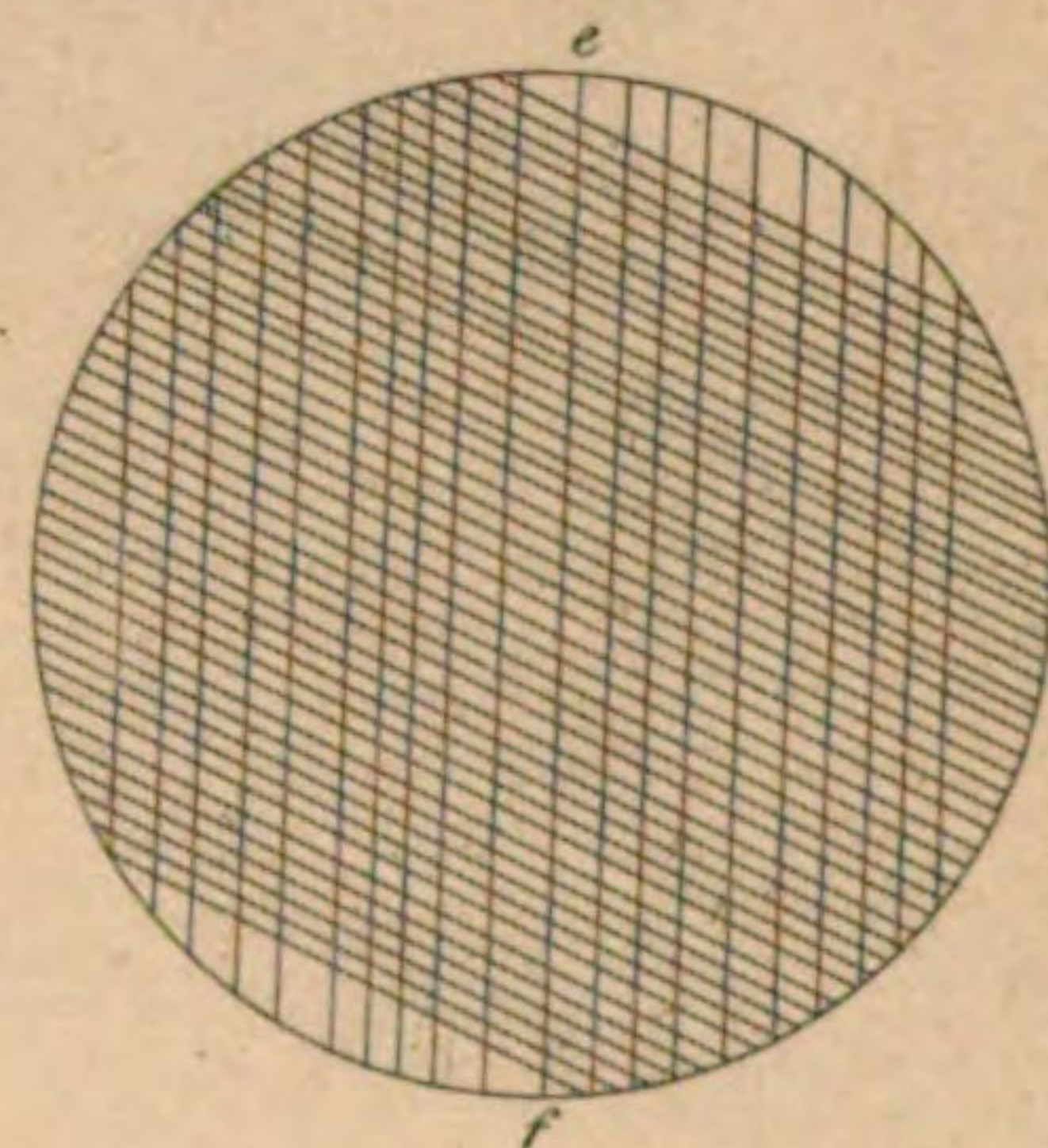


Fig. 35.

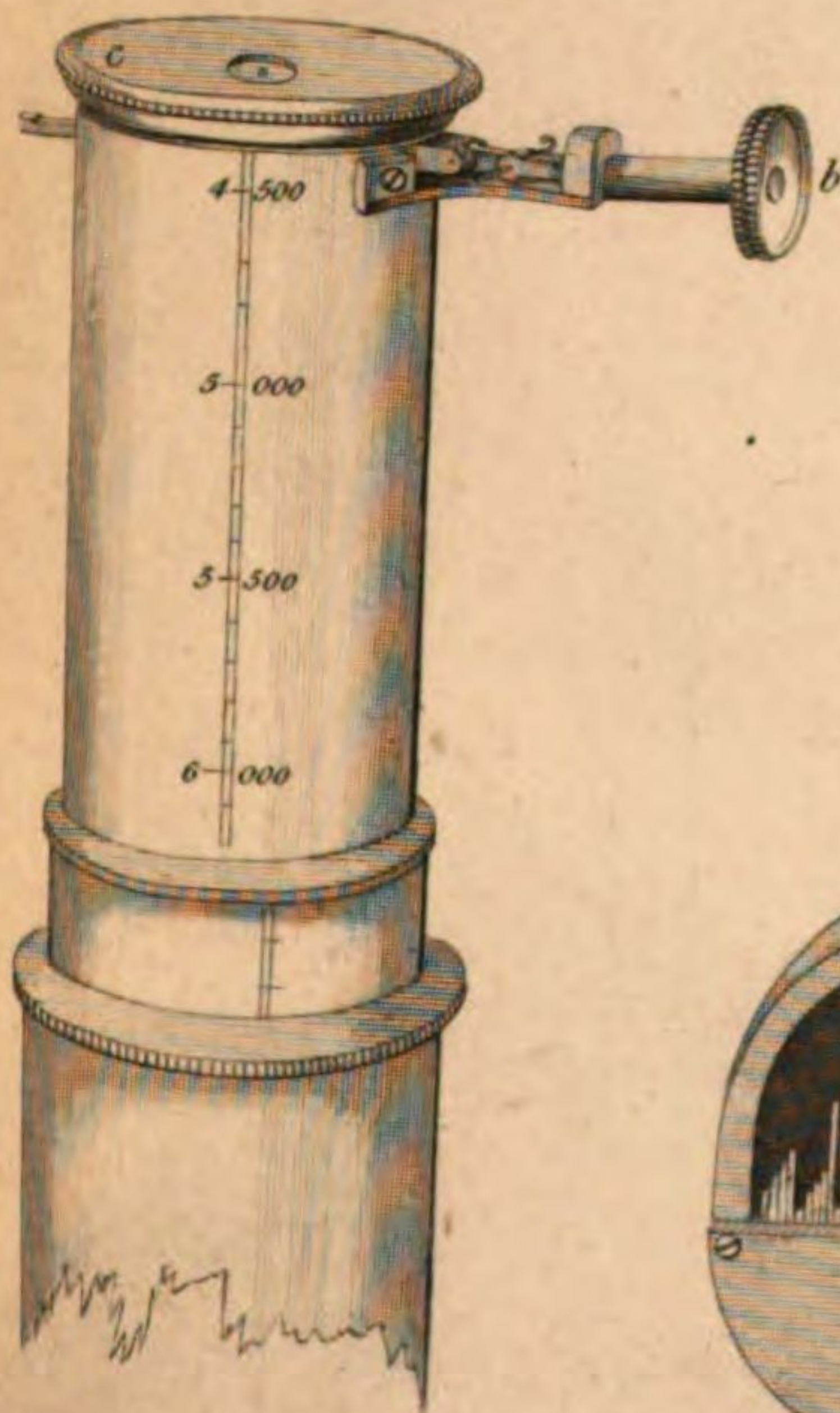


Fig. 30.

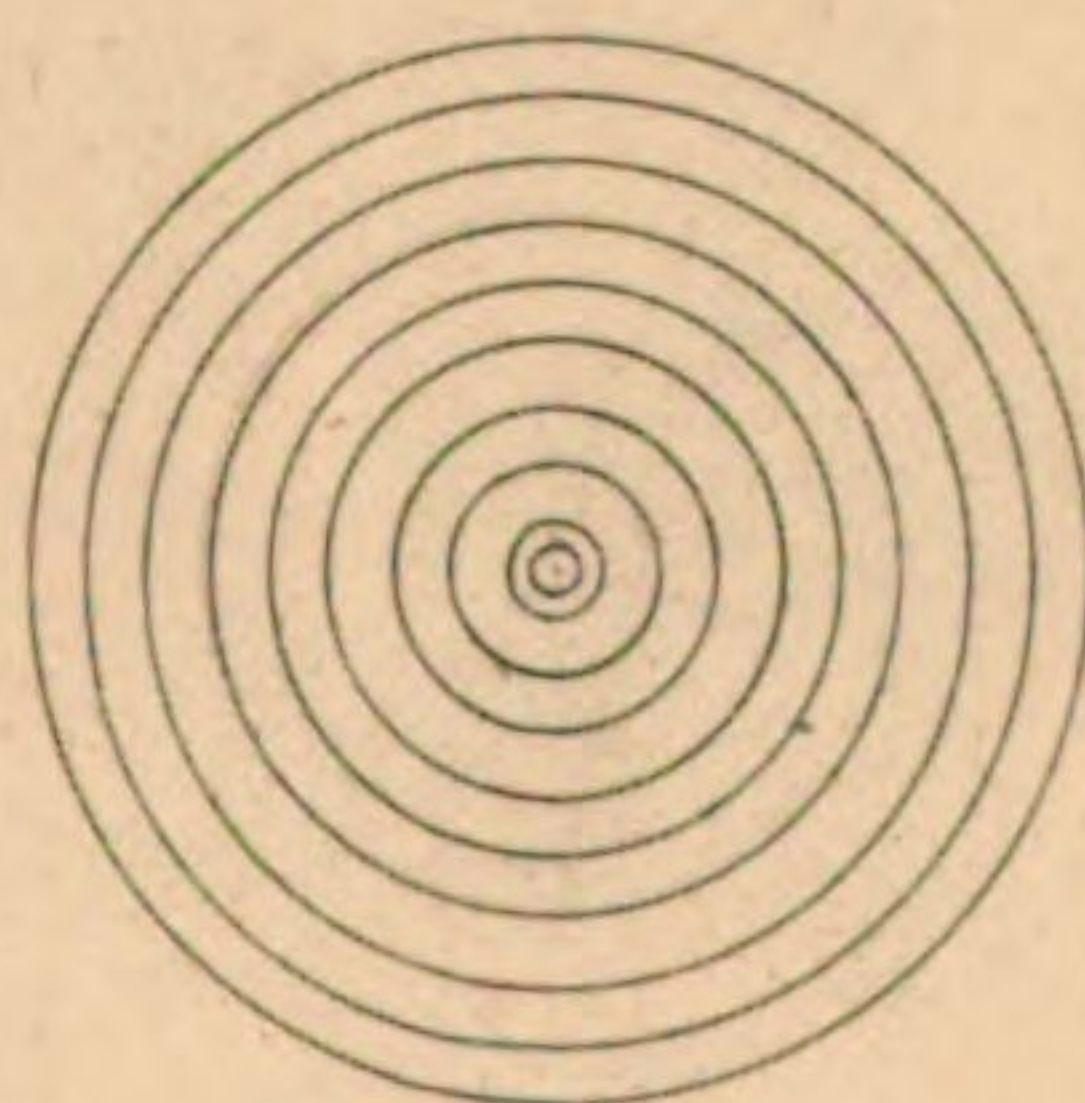


Fig. 31.

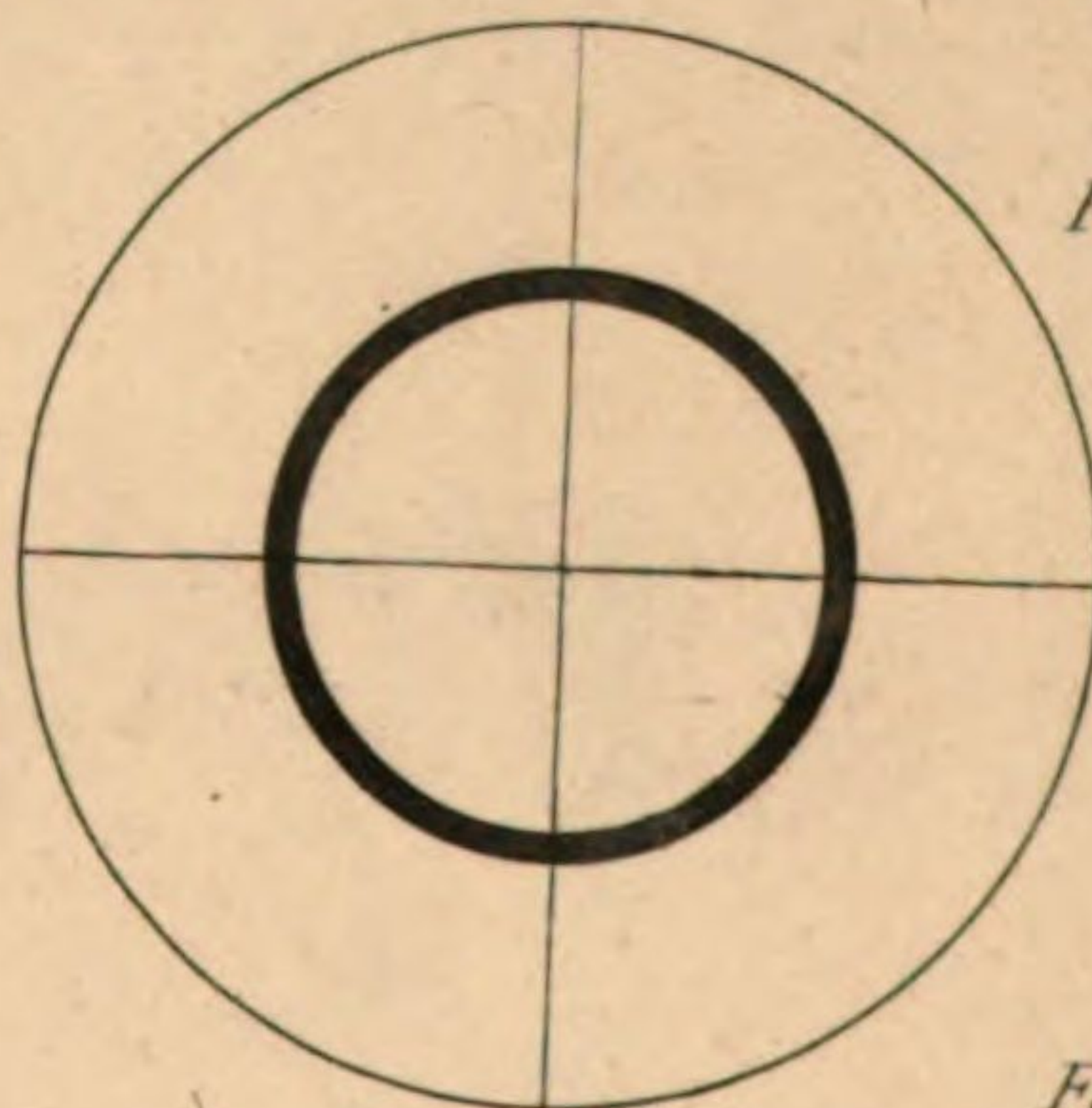


Fig. 34.

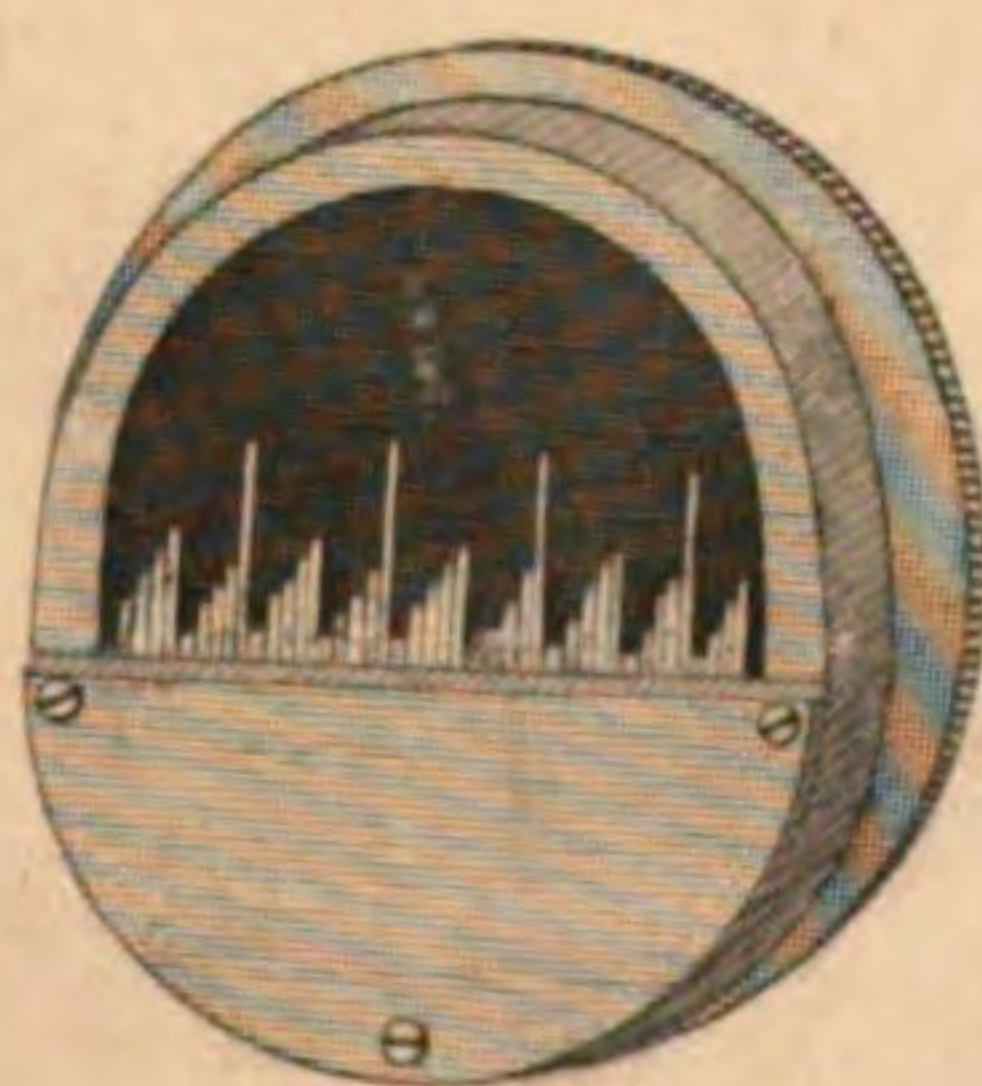


Fig. 32.



Fig. 36.

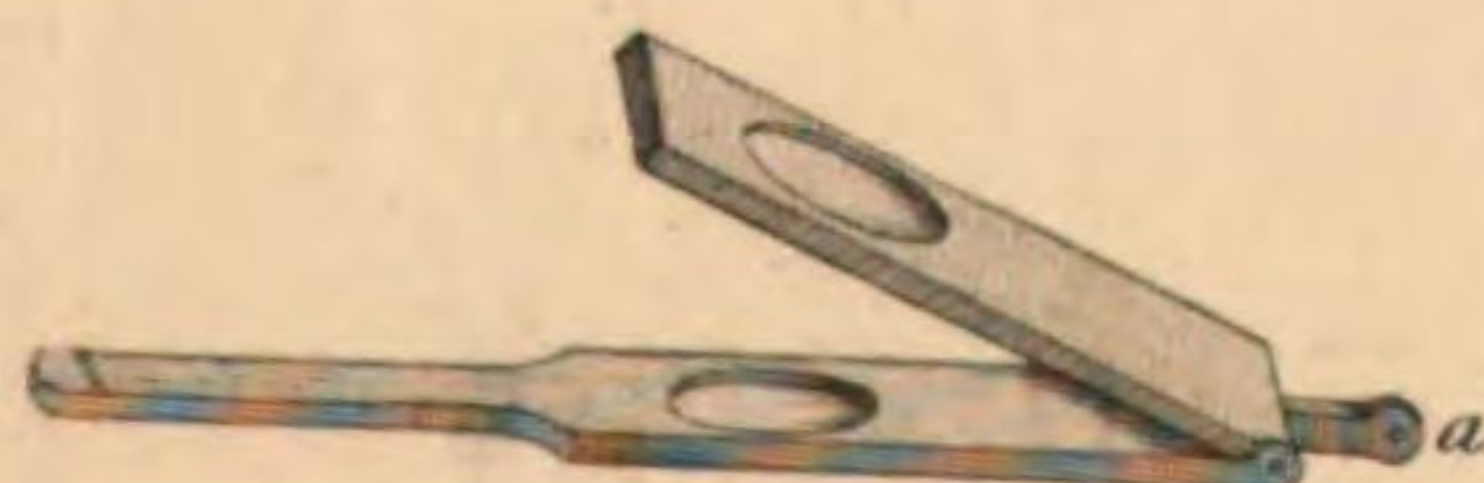
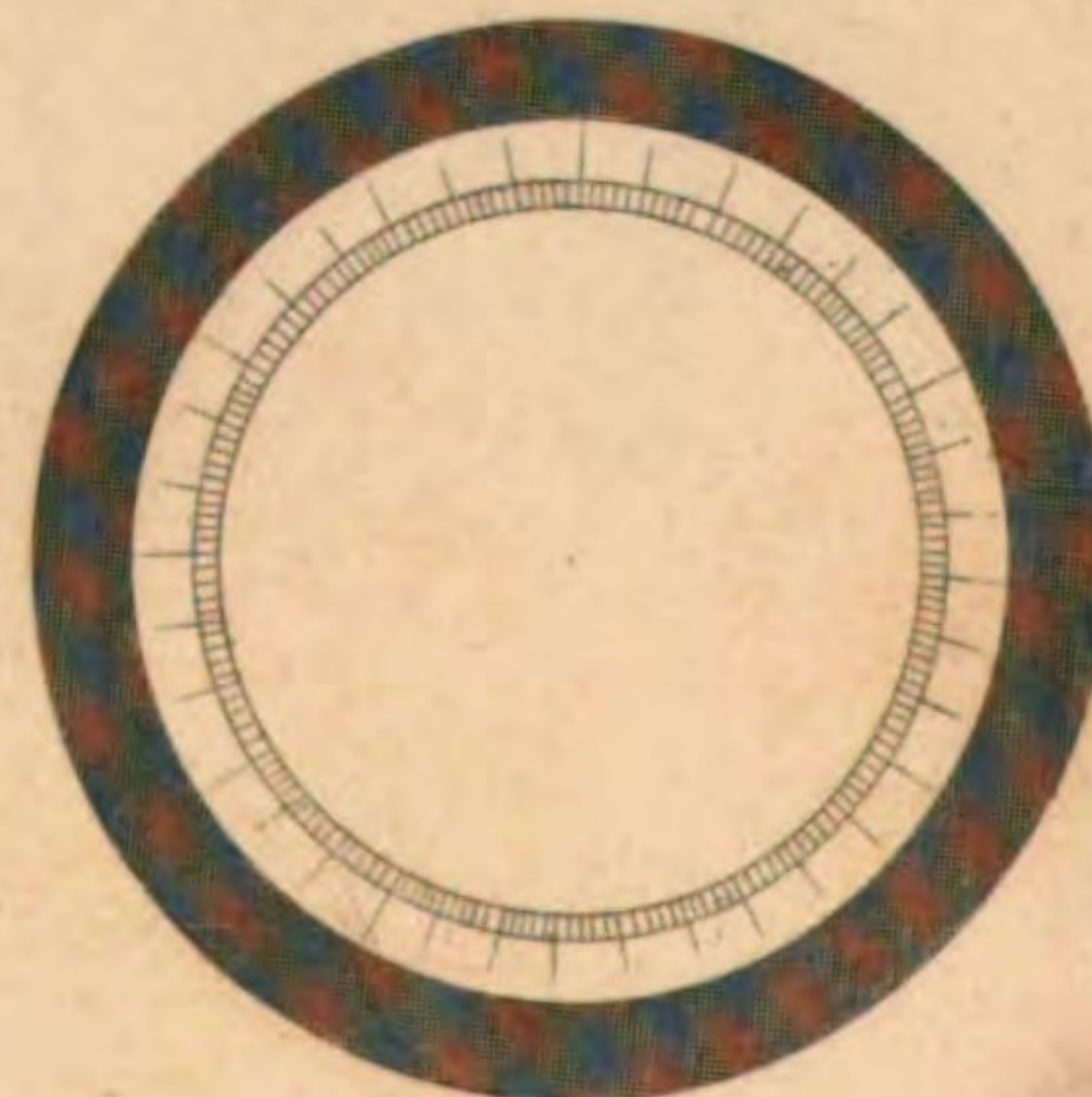


Fig. 33.



MICROSCOPE.

PLATE CCCLIX.

Fig. 1.



Fig. 2.

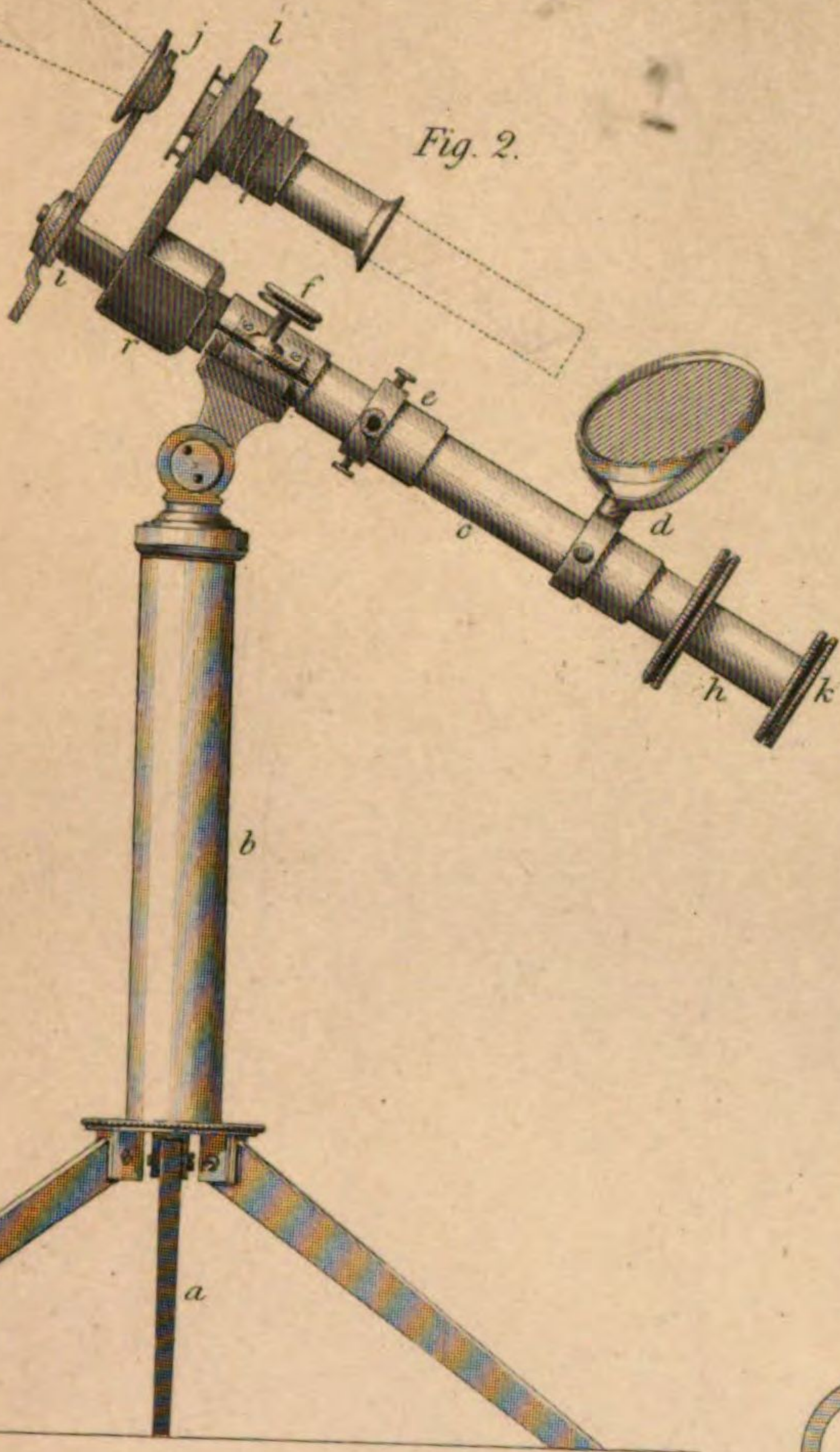


Fig. 4.

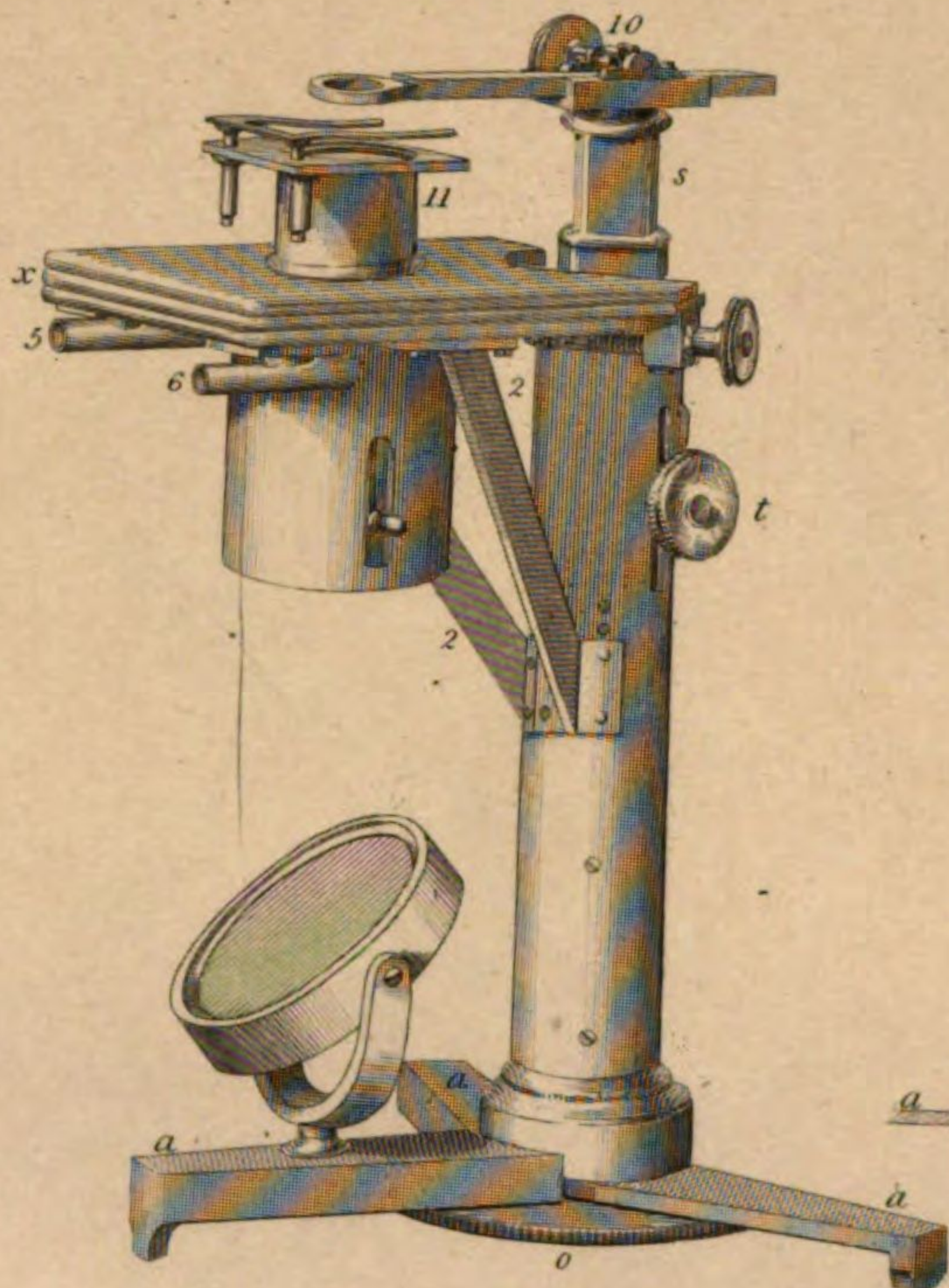


Fig. 5.

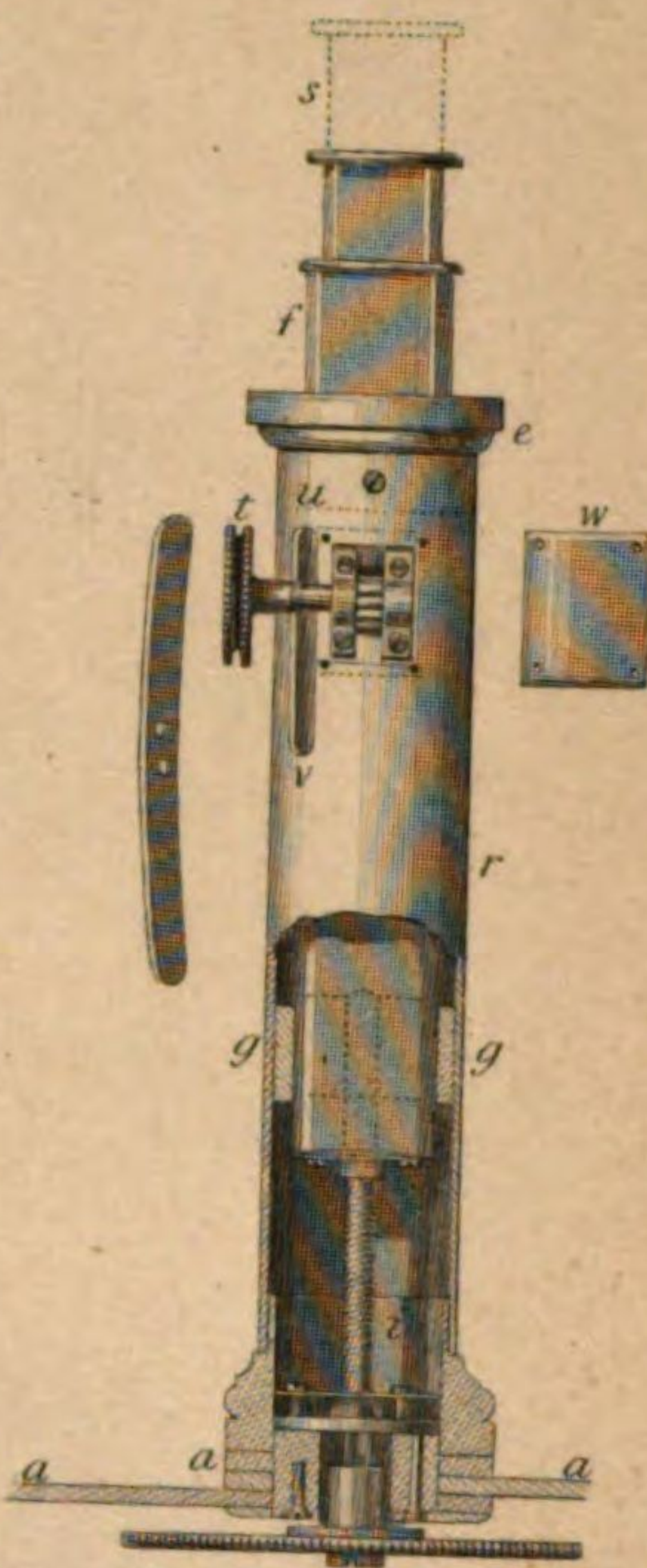


Fig. 3.

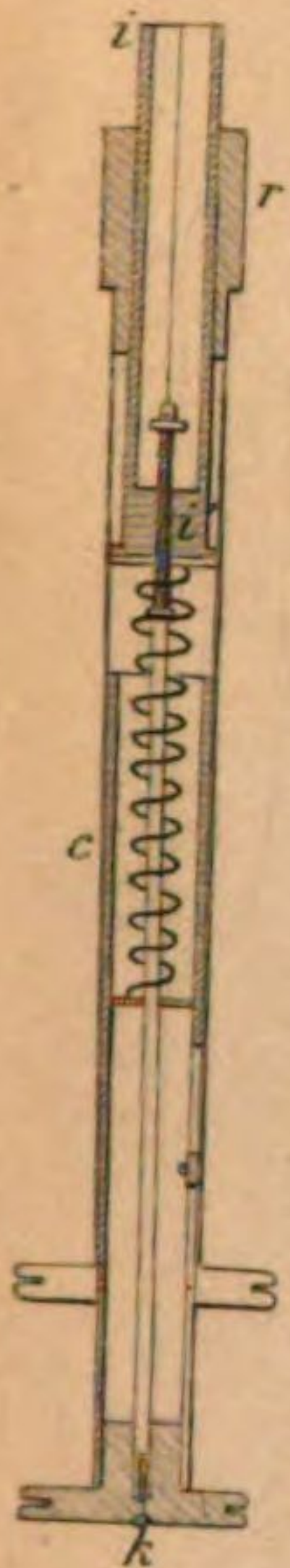


Fig. 6.

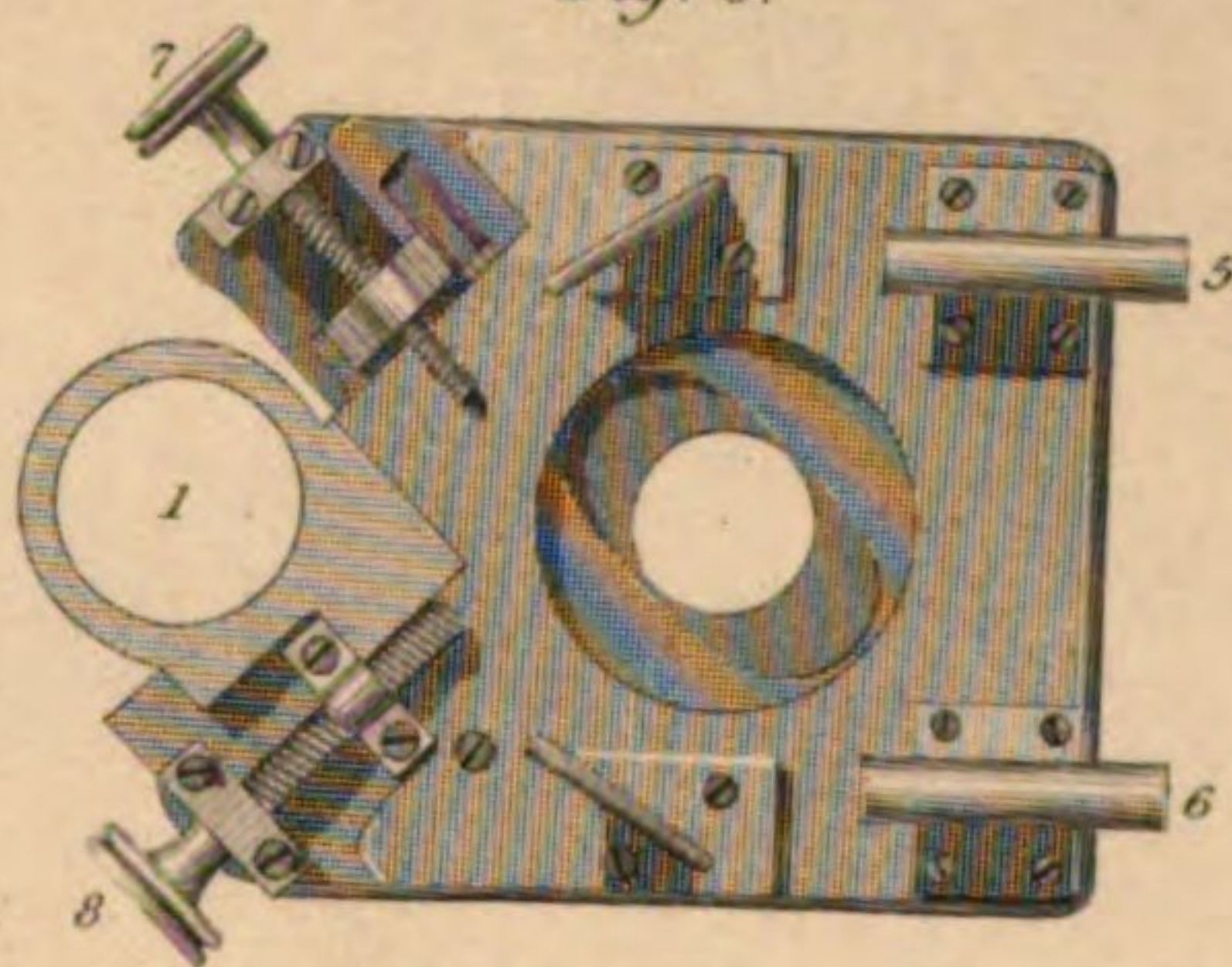


Fig. 7.

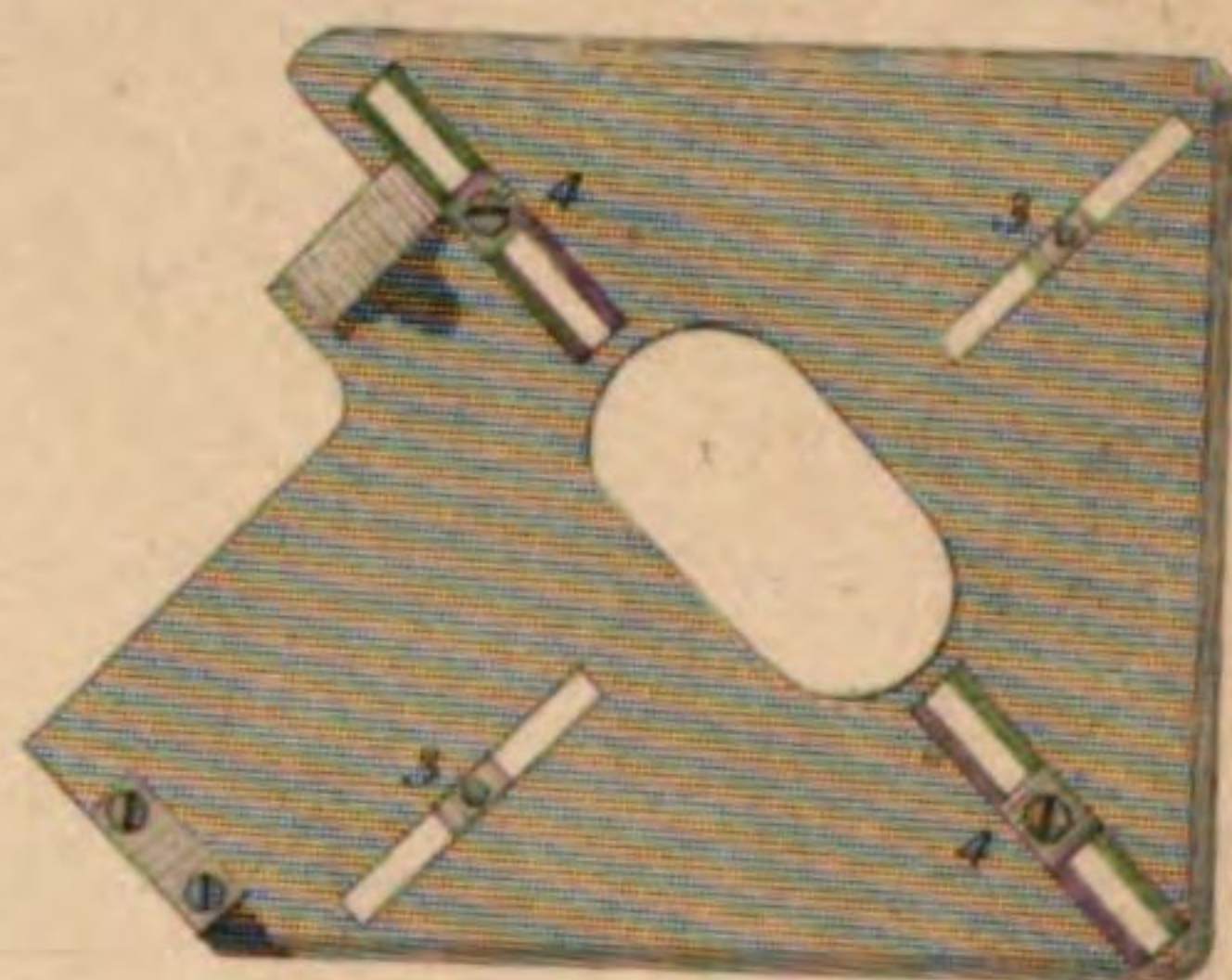


Fig. 8.

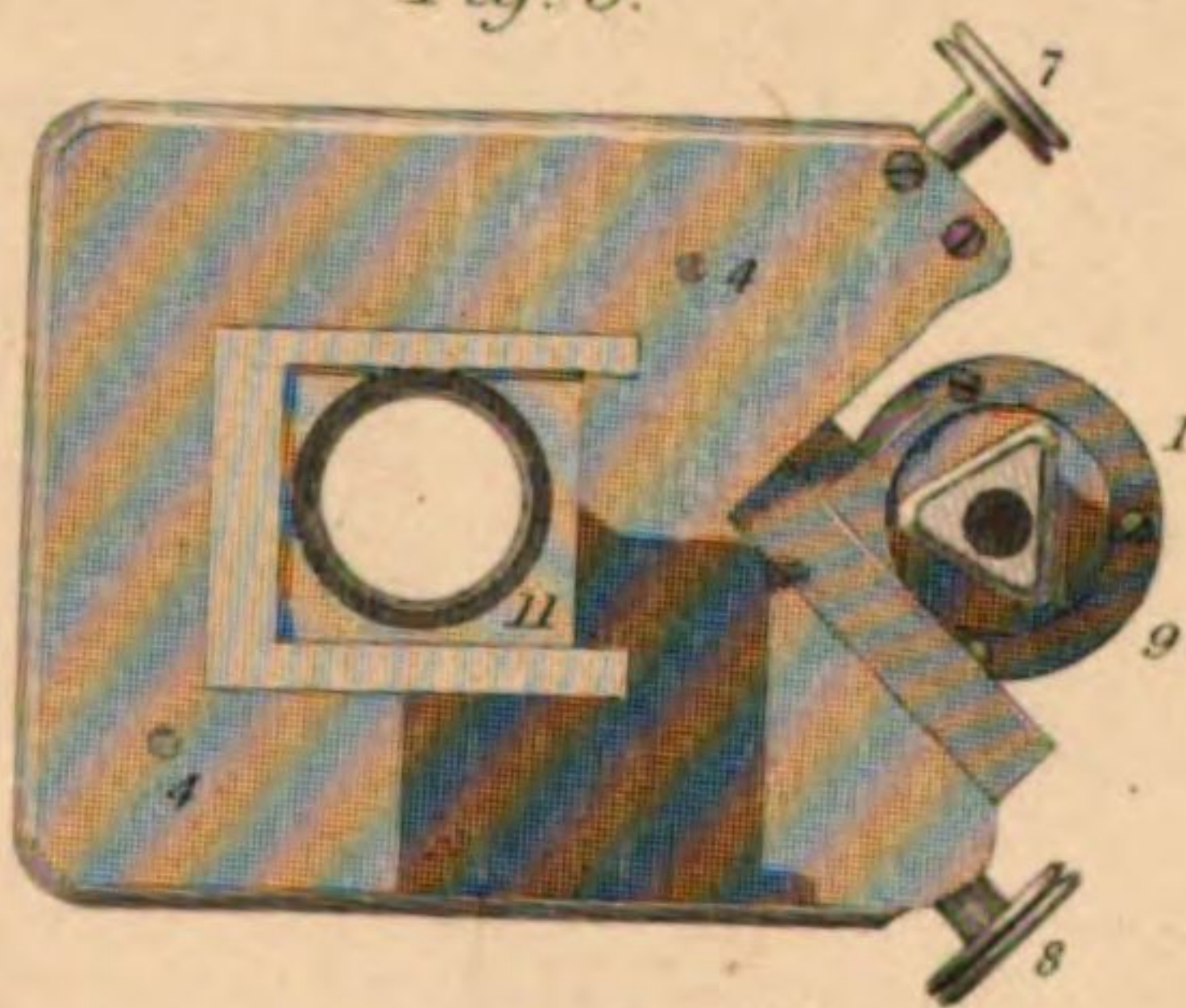


Fig. 10.

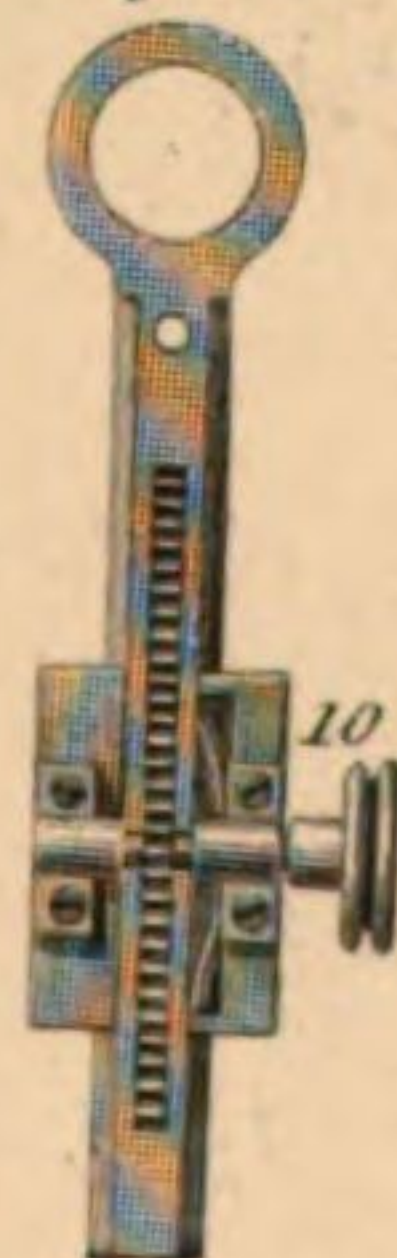


Fig. 16.

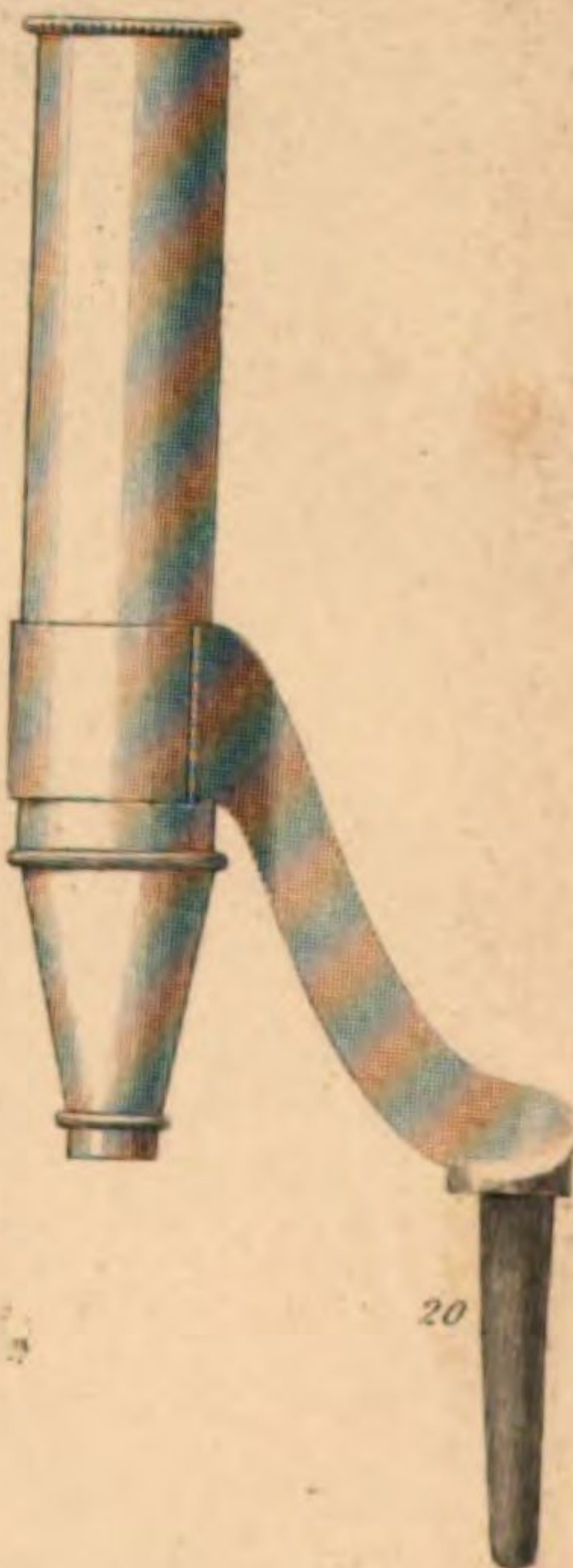


Fig. 15.

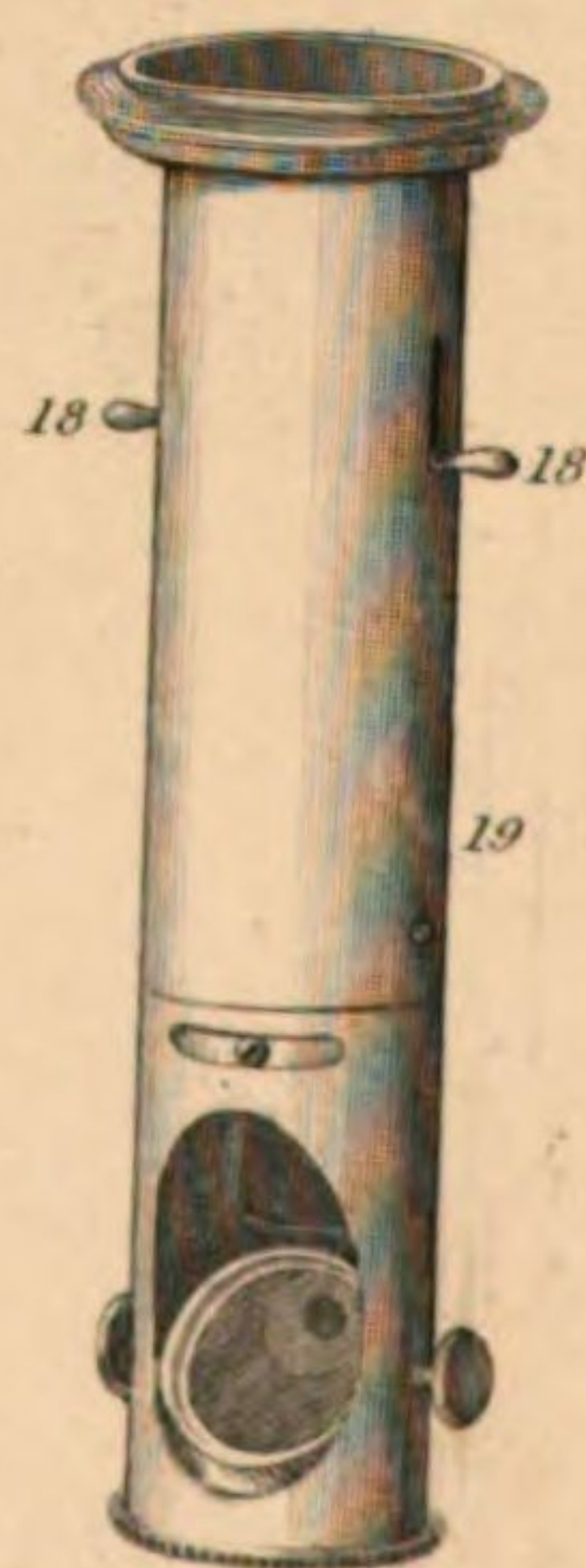


Fig. 17. 18.



Fig. 11.

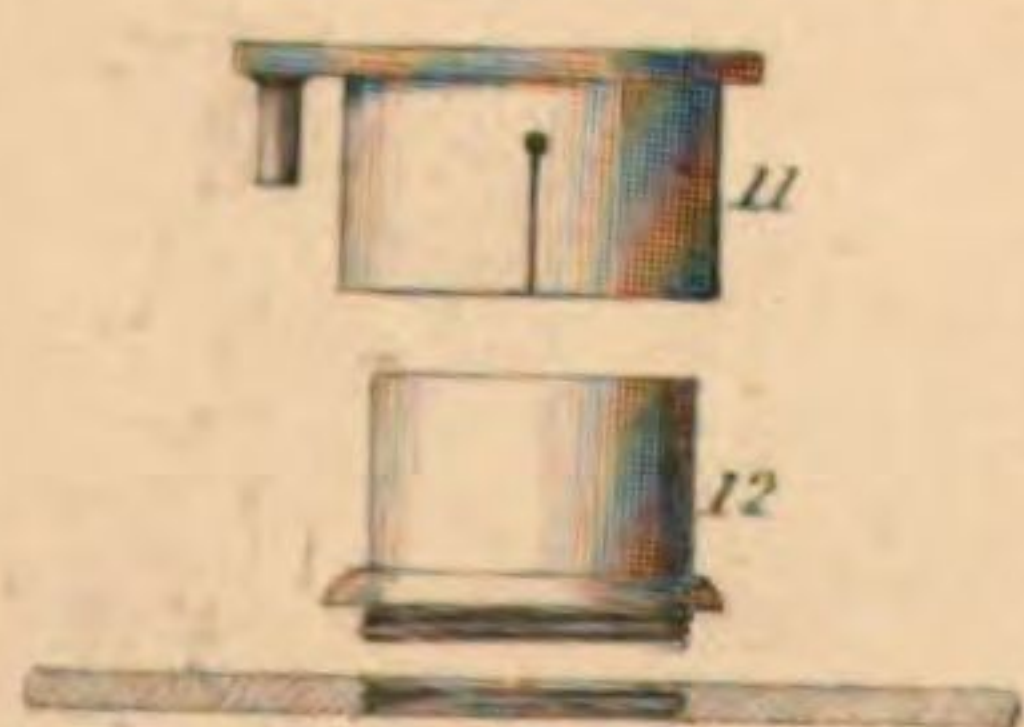


Fig. 14.

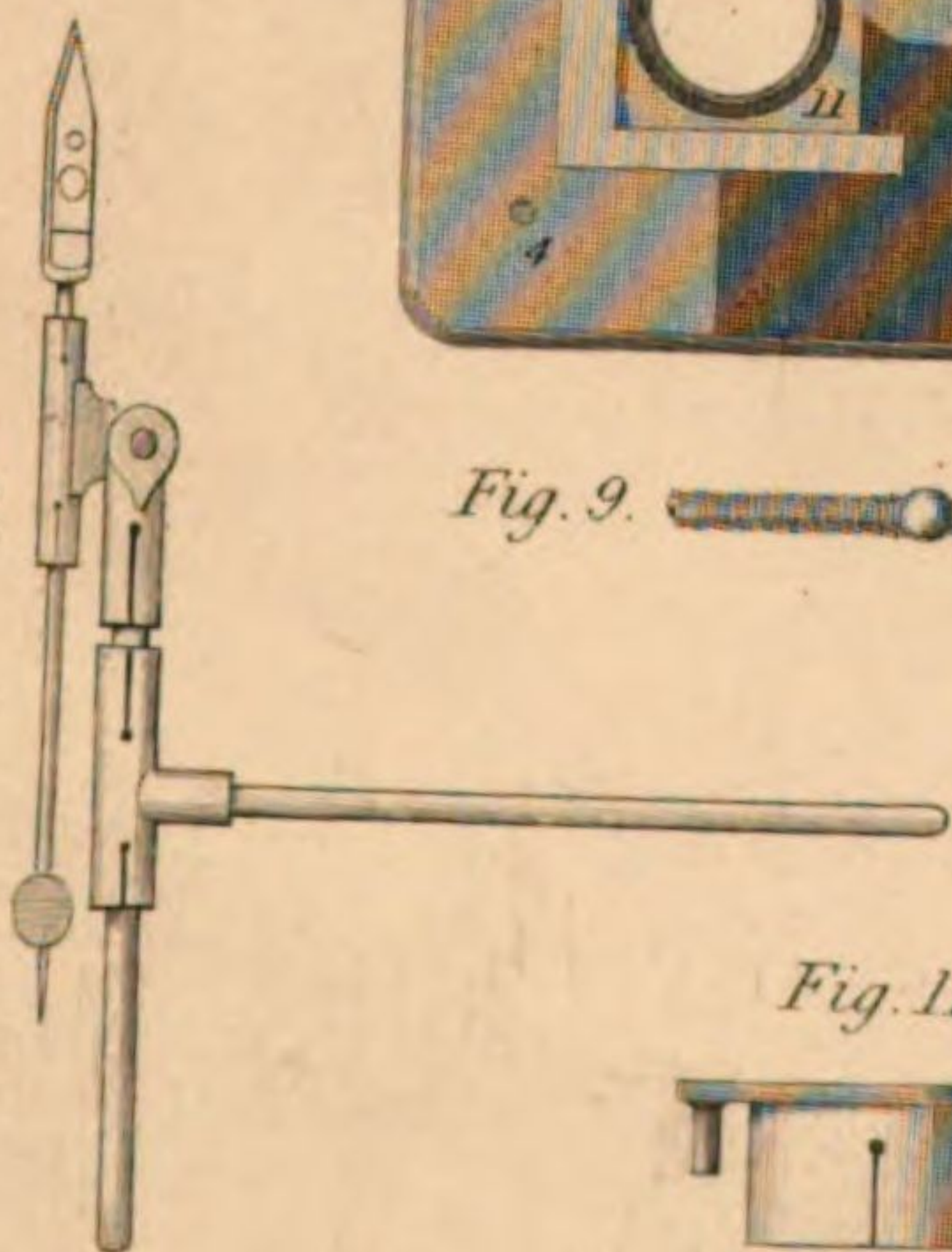


Fig. 12.



Fig. 13.

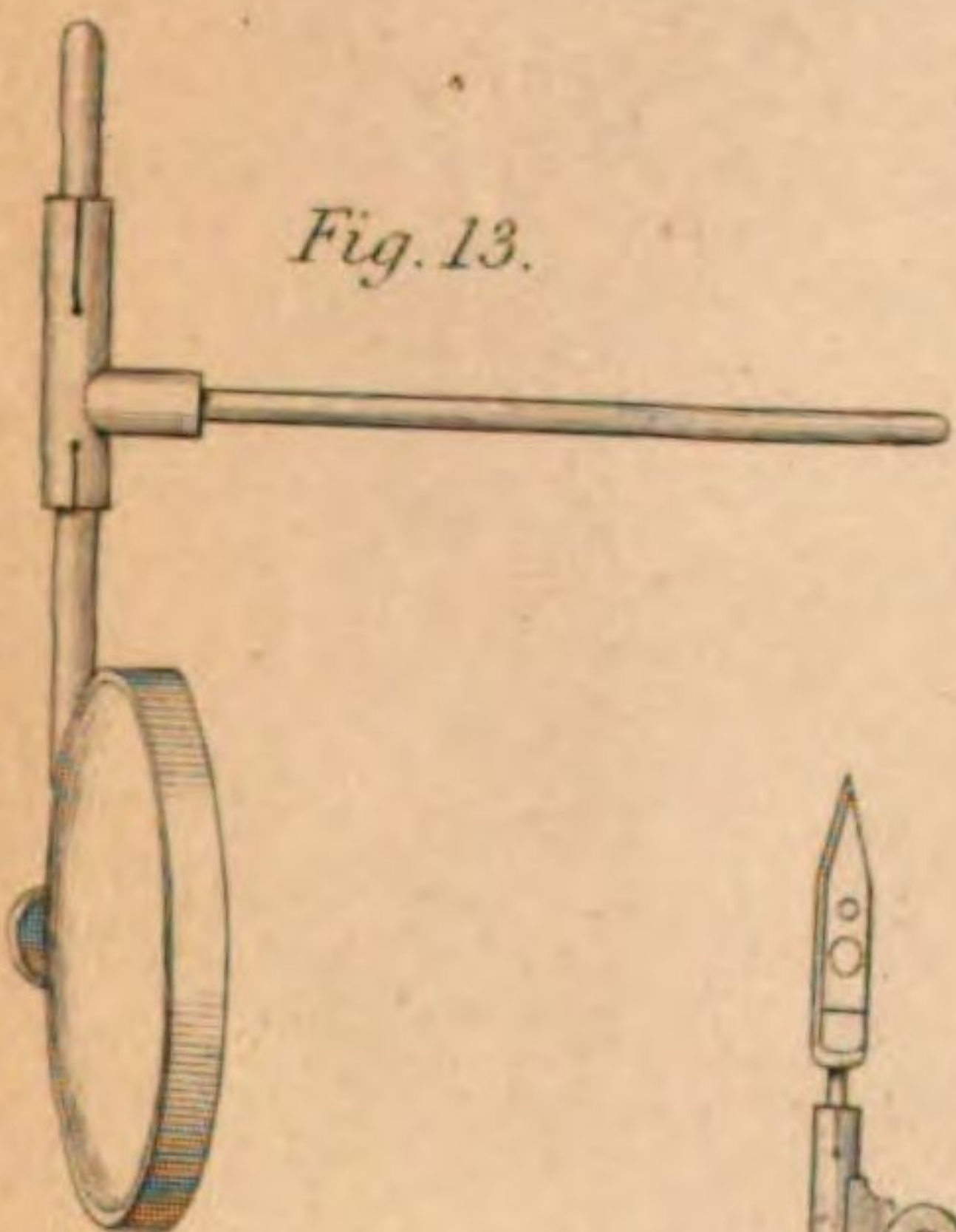


Fig. 19.

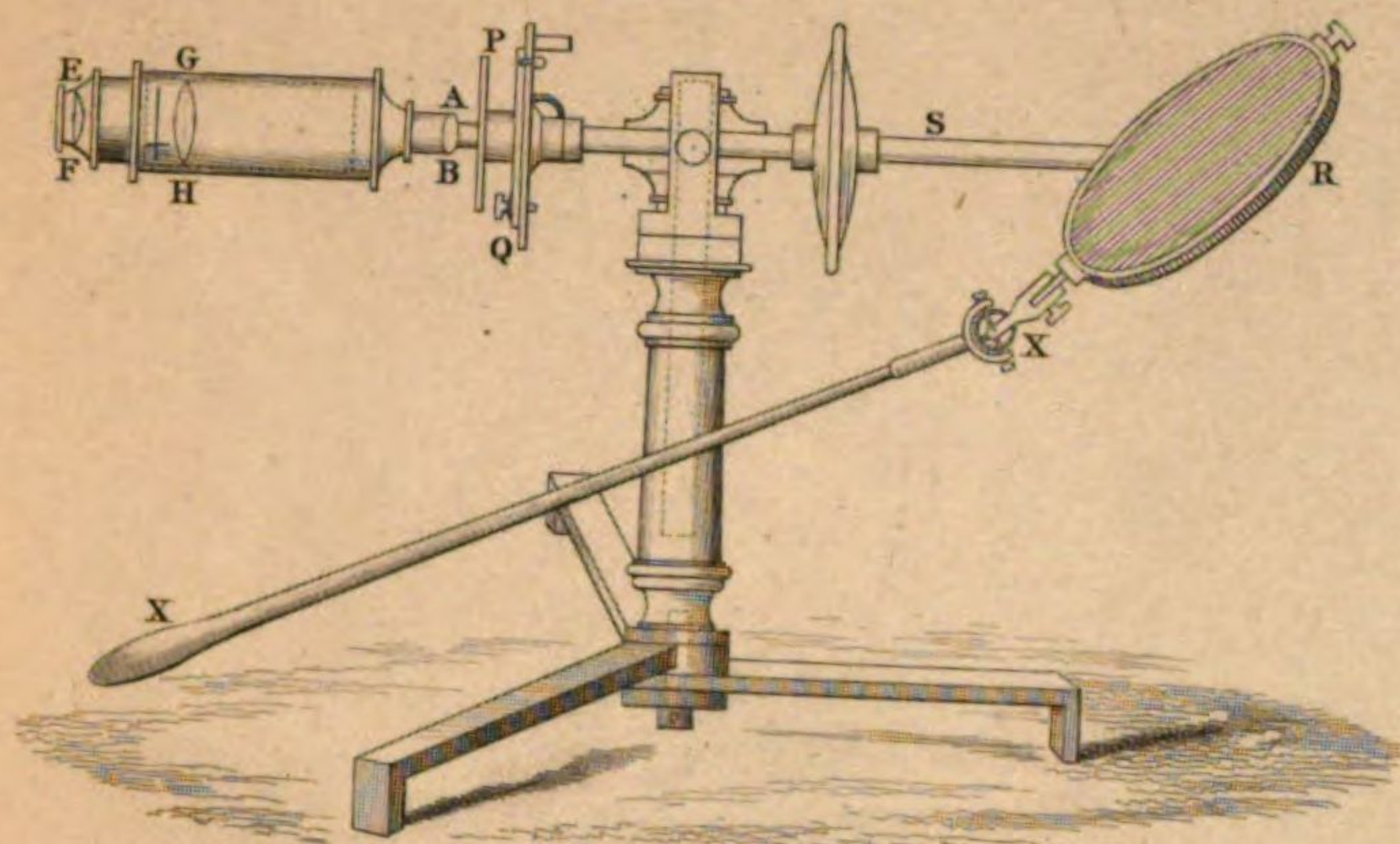


Fig. 22.

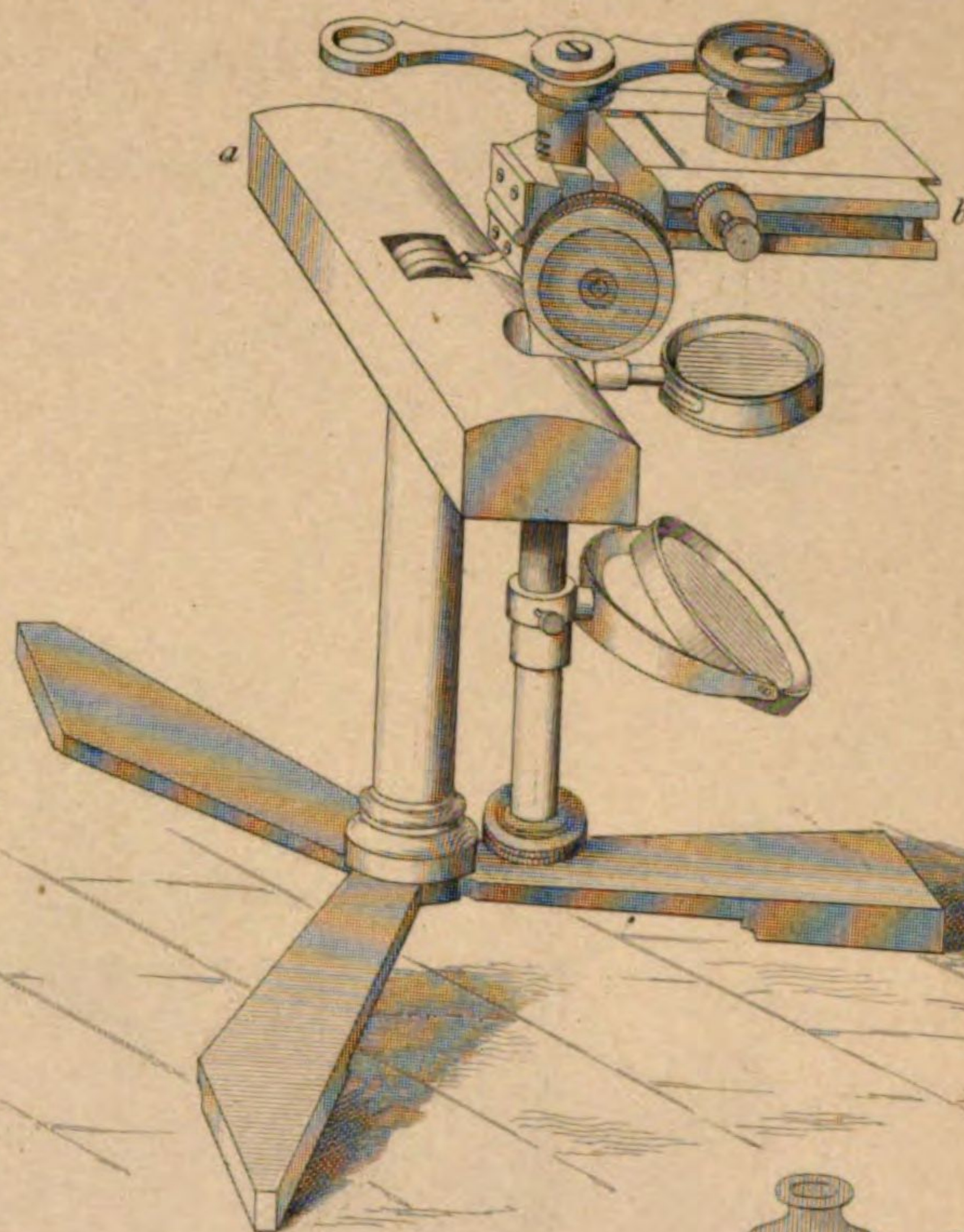


Fig. 20.

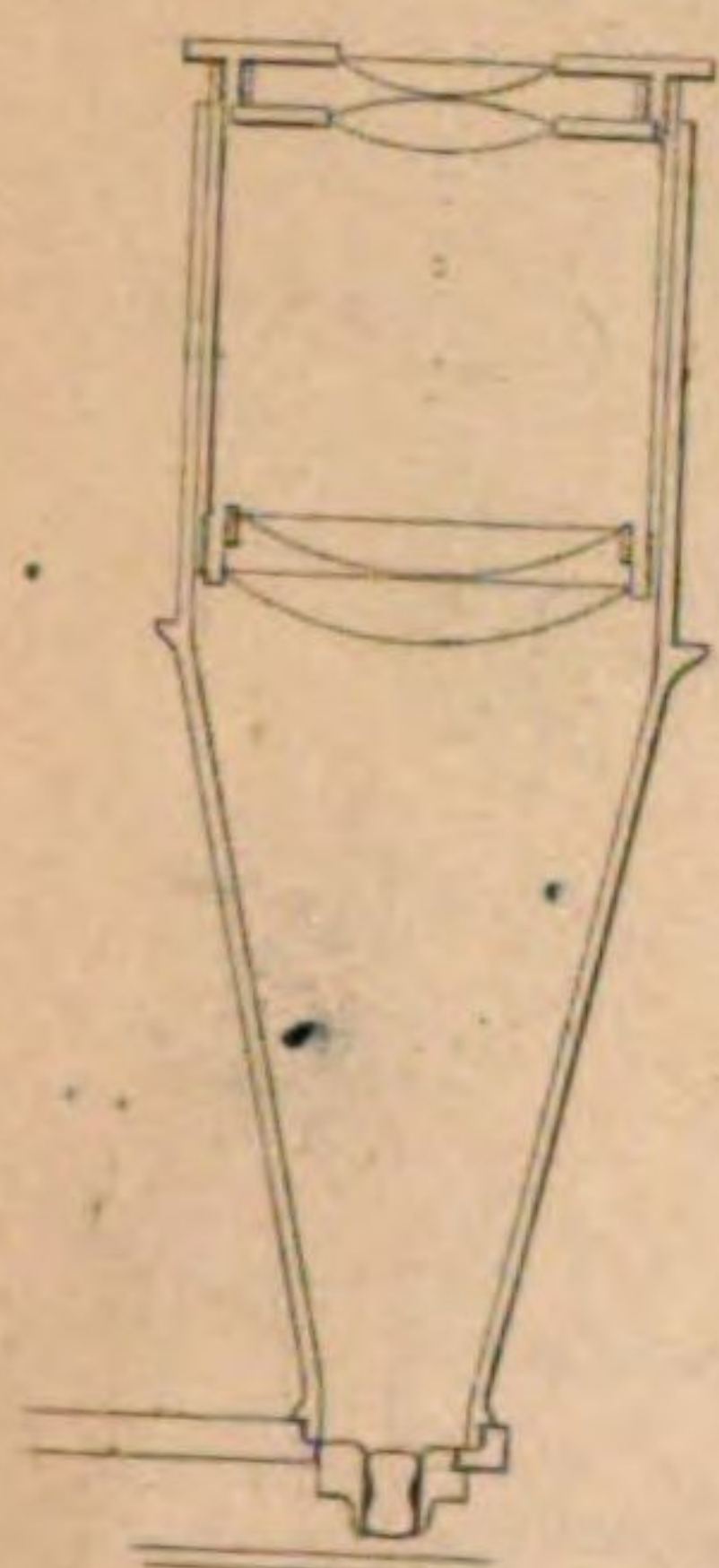


Fig. 24.



Fig. 25.

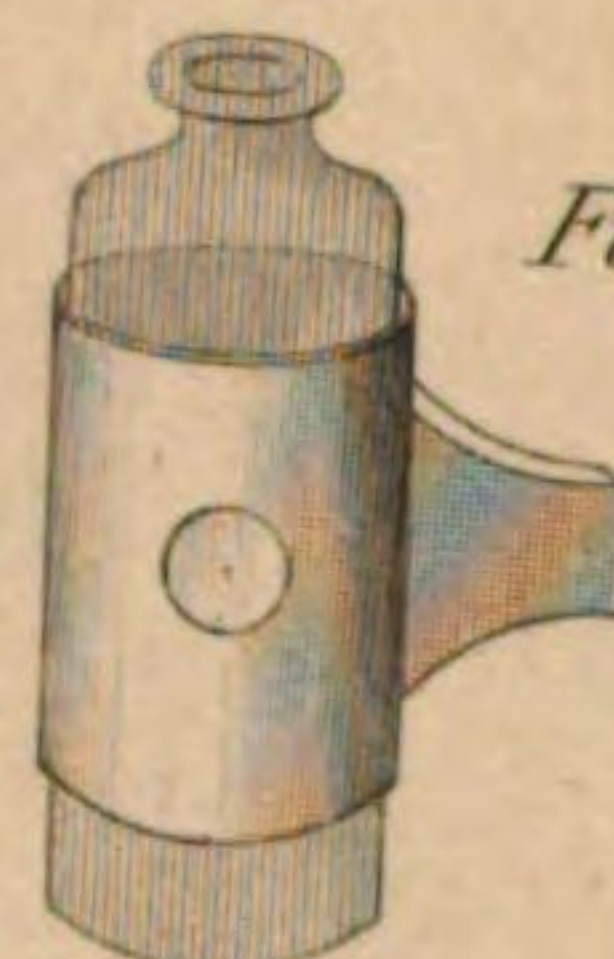


Fig. 23.

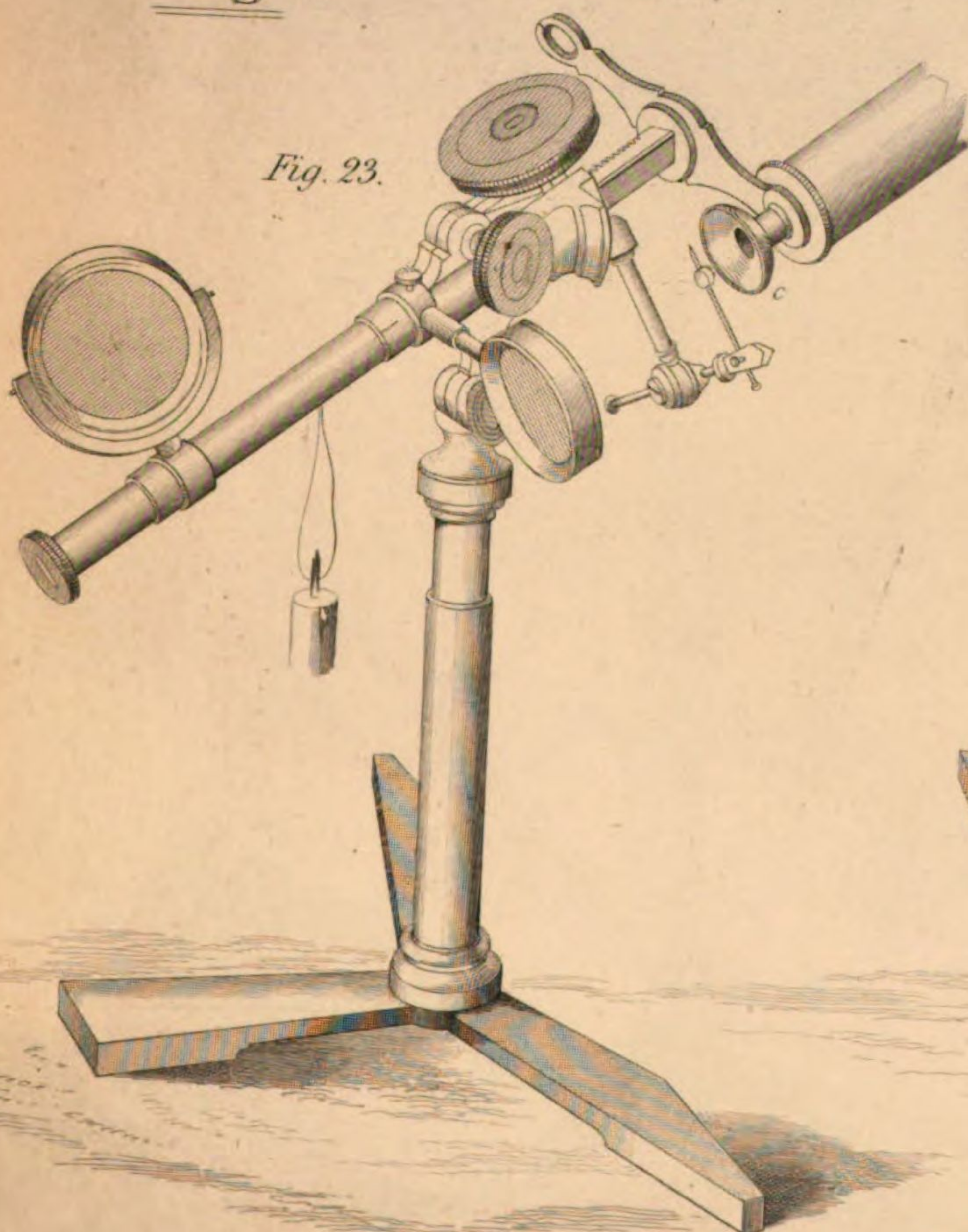


Fig. 21.

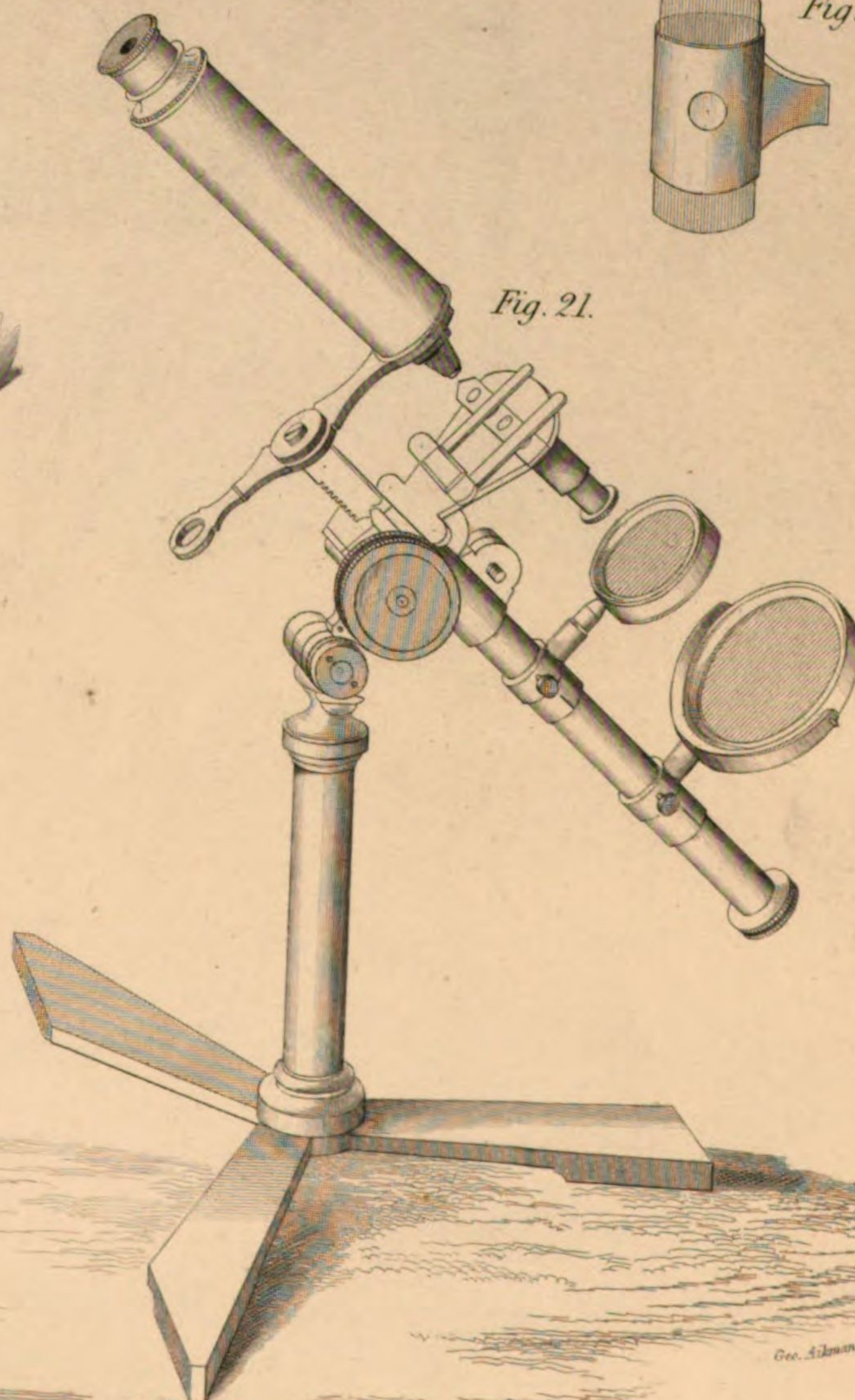


Fig. 26.

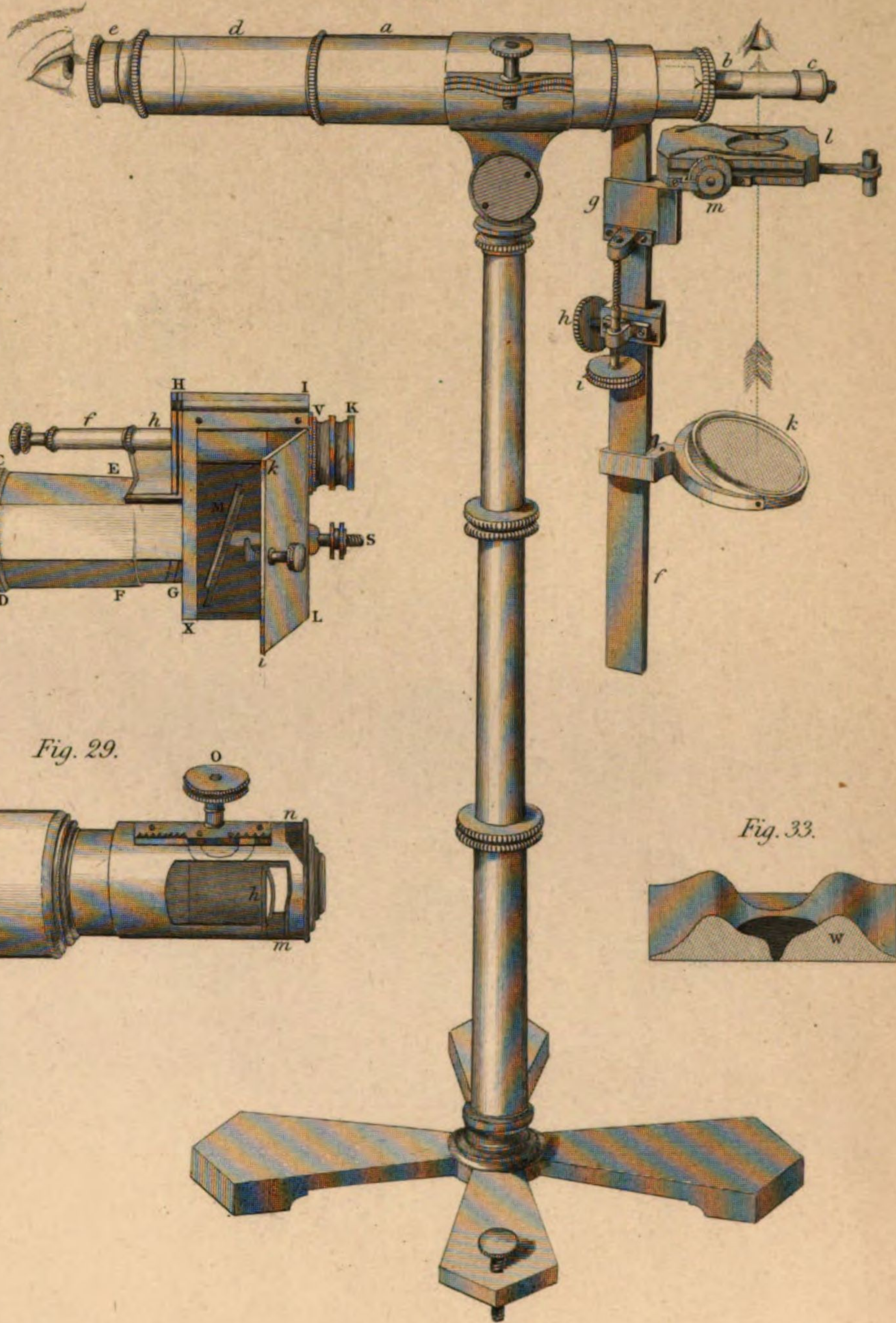


Fig. 27.

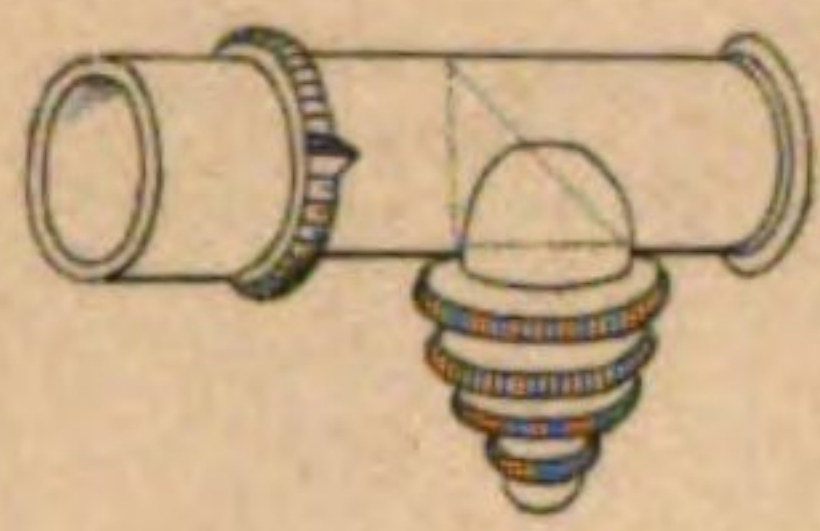


Fig. 28.

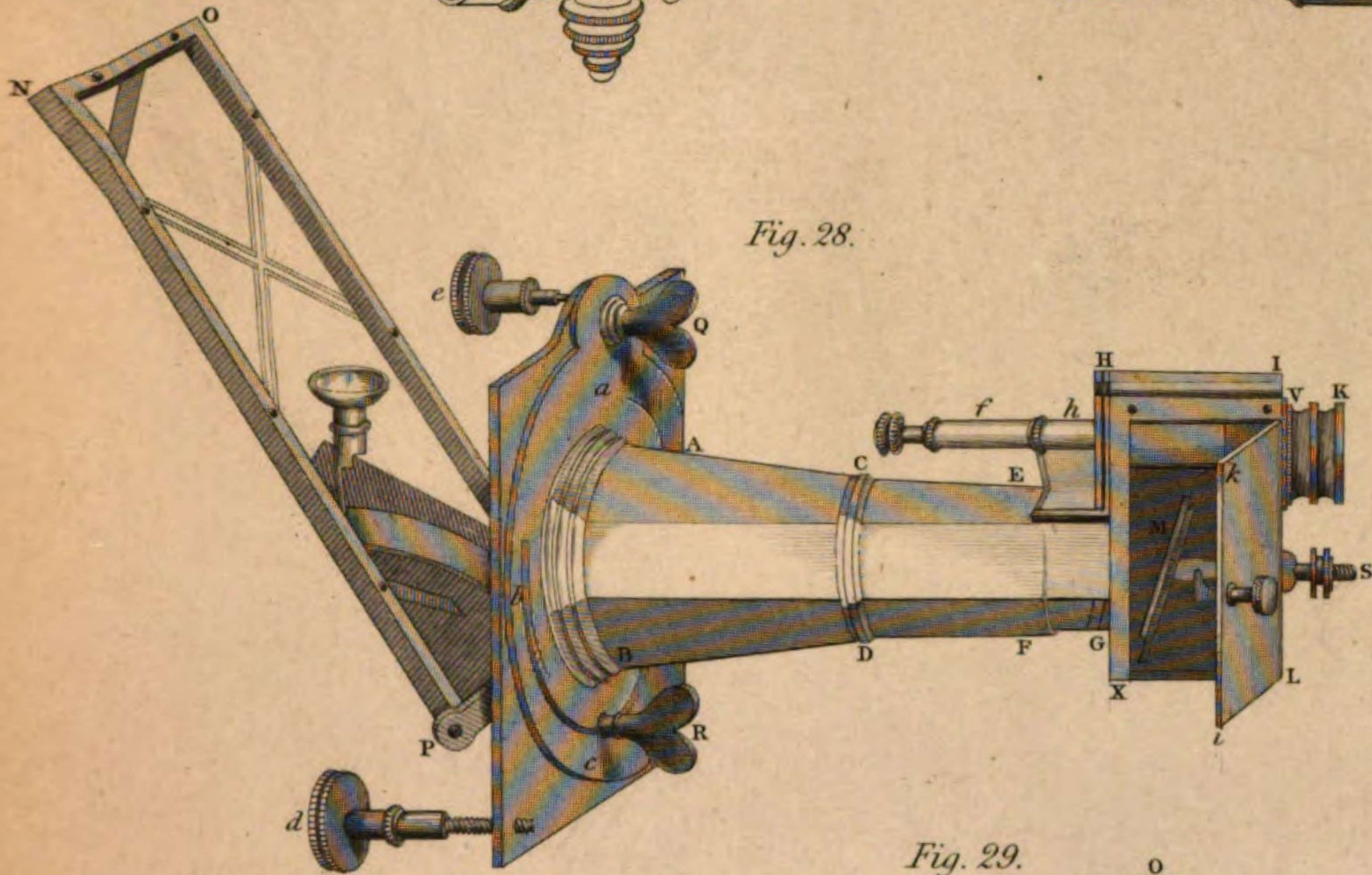


Fig. 29.

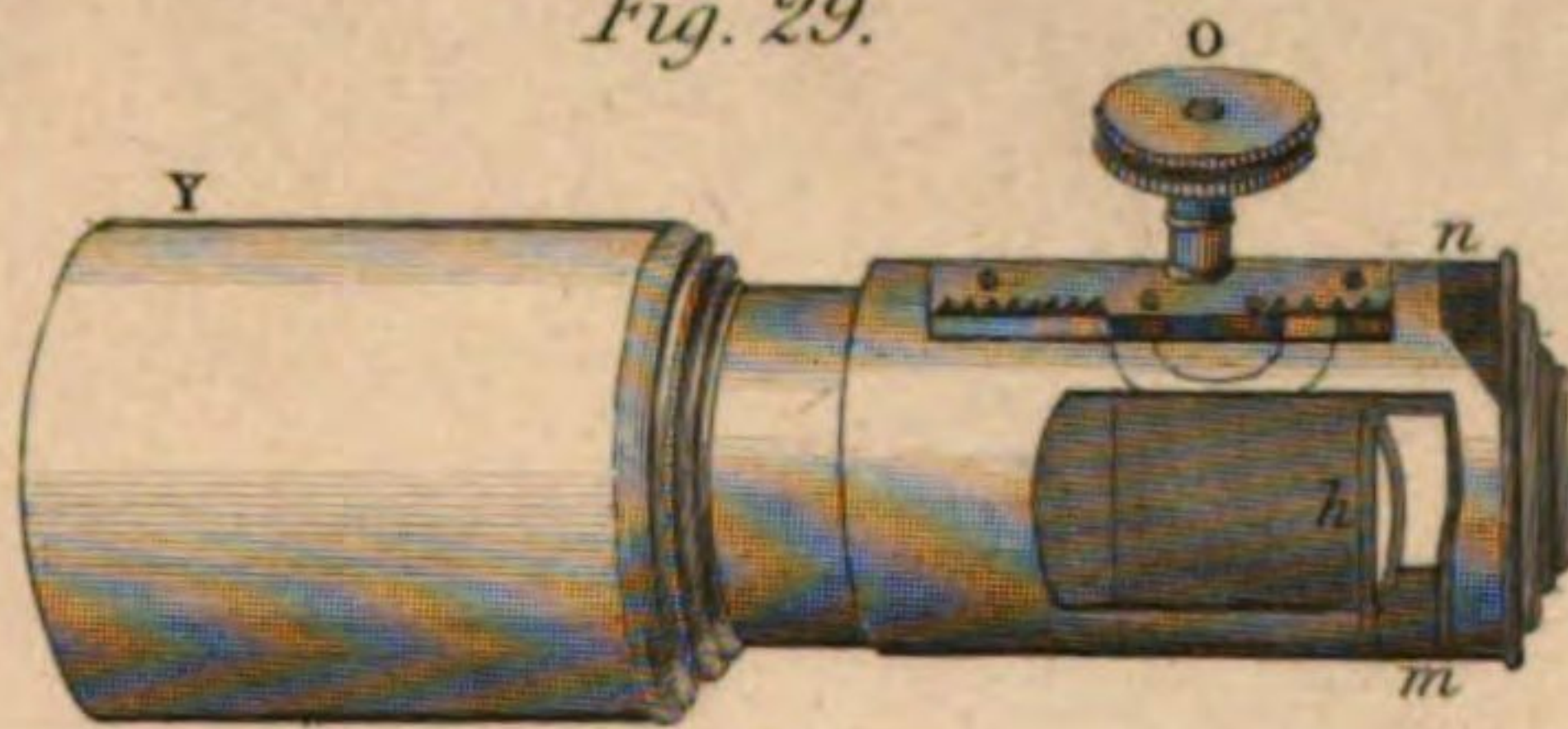


Fig. 32.

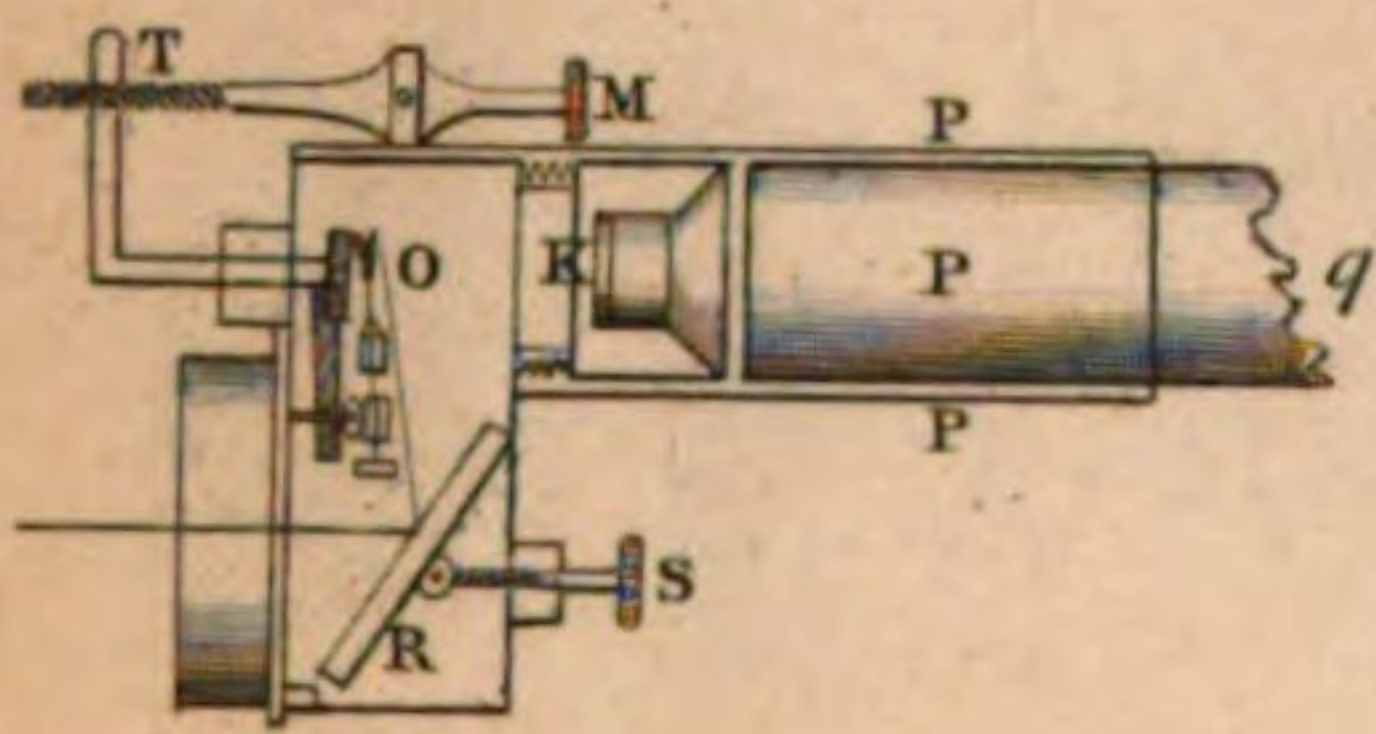


Fig. 33.



Fig. 30.

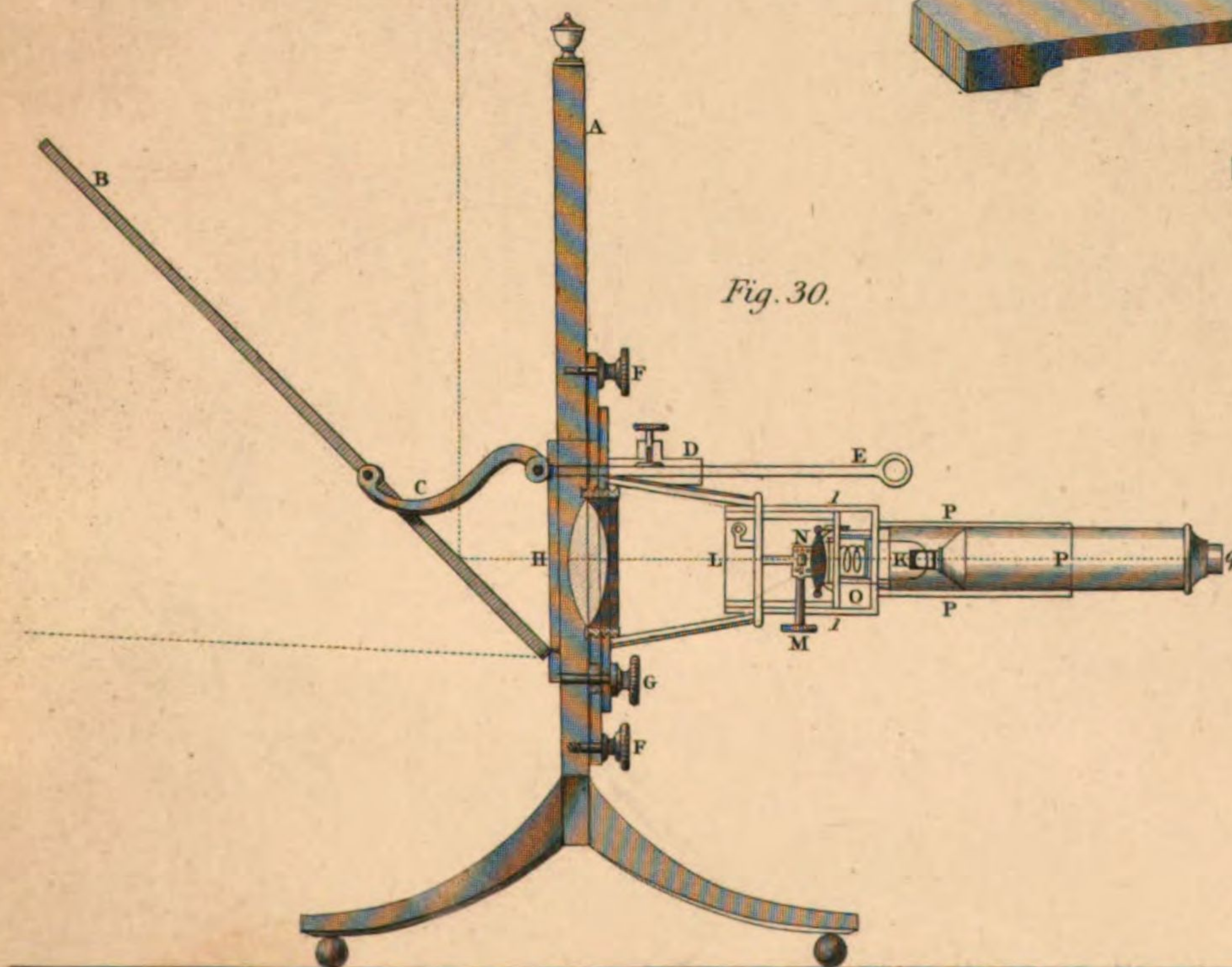
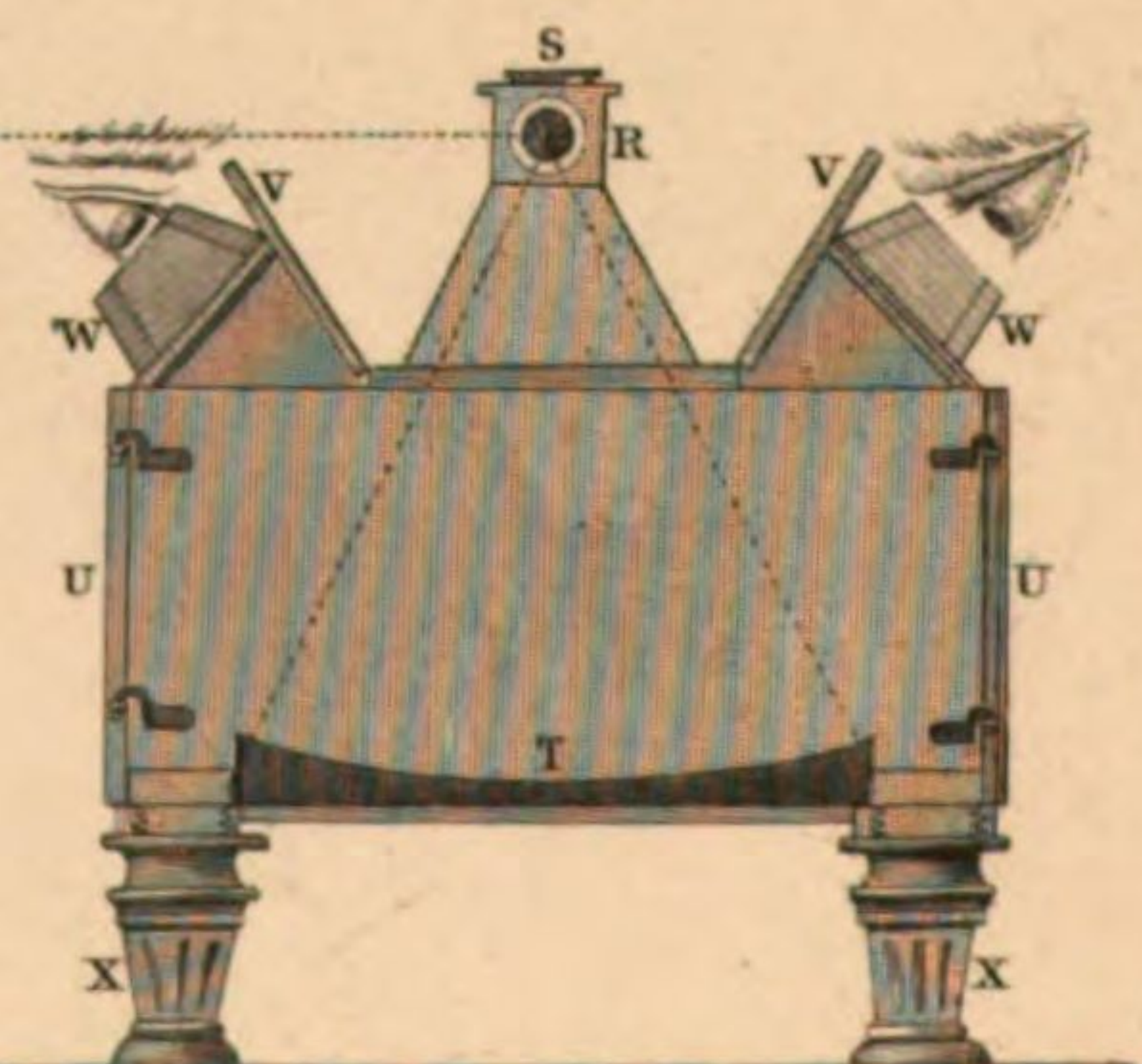
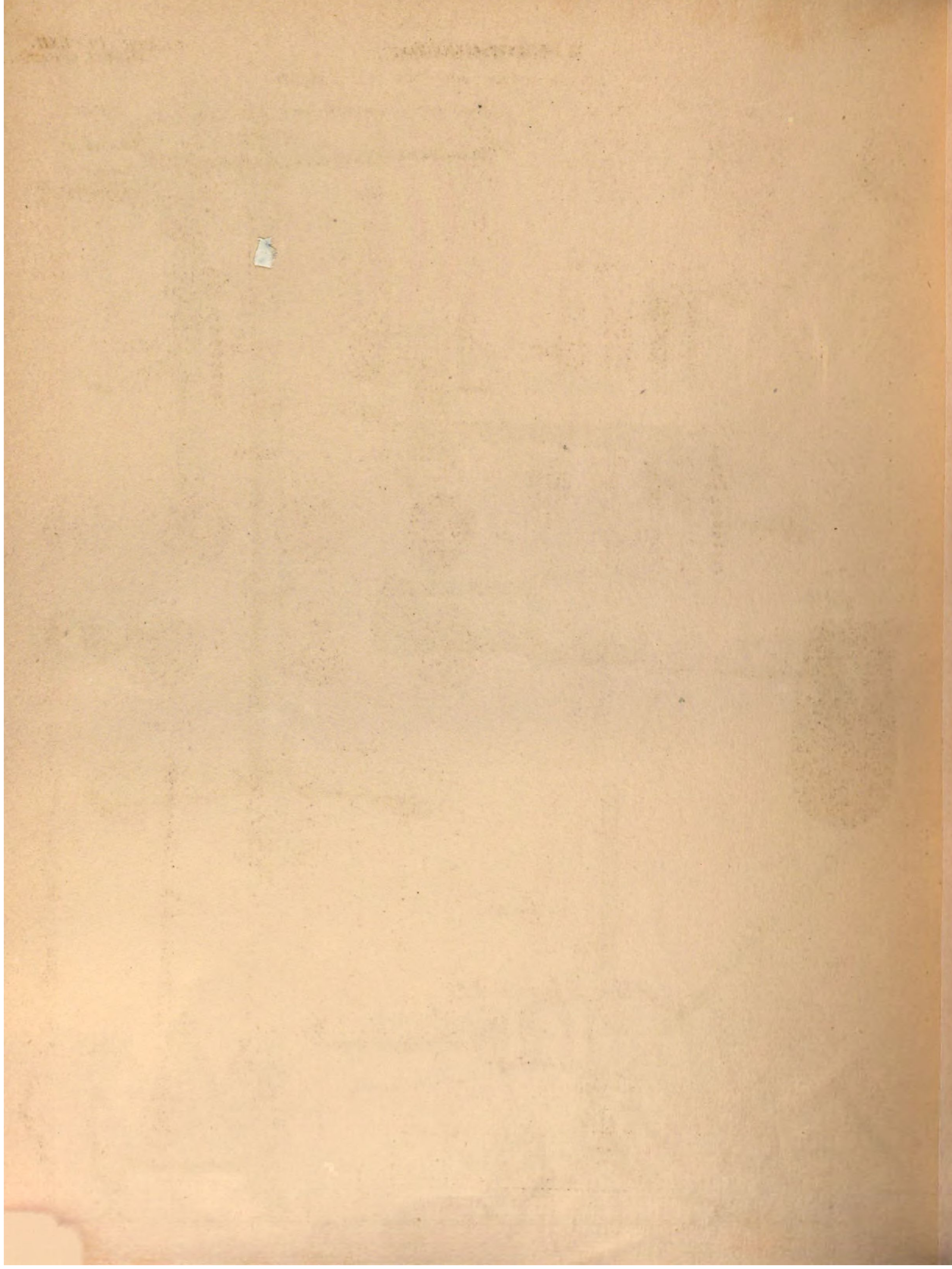


Fig. 31.





MICROSCOPE.
MICROSCOPIC OBJECTS.

PLATE CCCLXII.

Fig. 1.



Fig. 2.



Fig. 3.



Fig. 4.



Fig. 5.



Fig. 6.

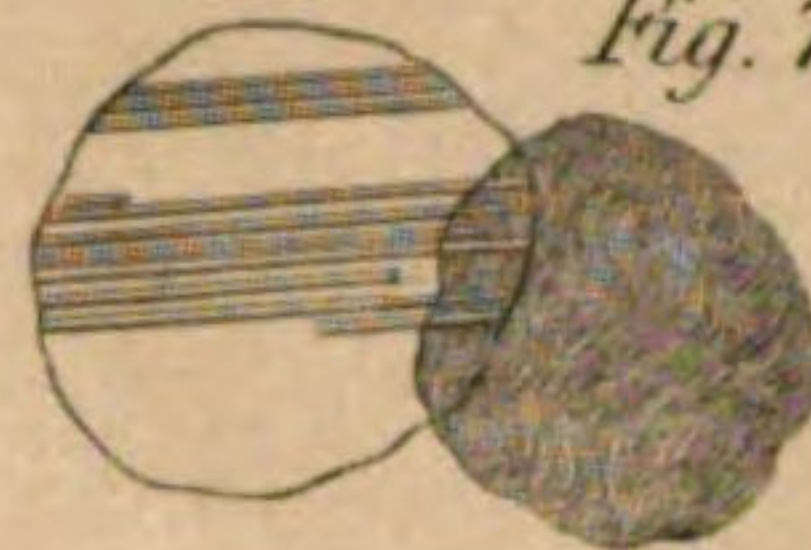


Fig. 7.



Fig. 8.

Fig. 9.



Fig. 10.



Fig. 12.



Fig. 13.



Fig. 14.



Fig. 15.



Fig. 11.



Fig. 18.



Fig. 19.



Fig. 20.



Fig. 21.



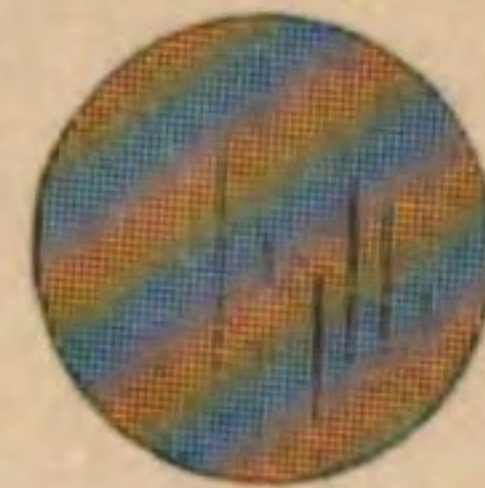
Fig. 22.



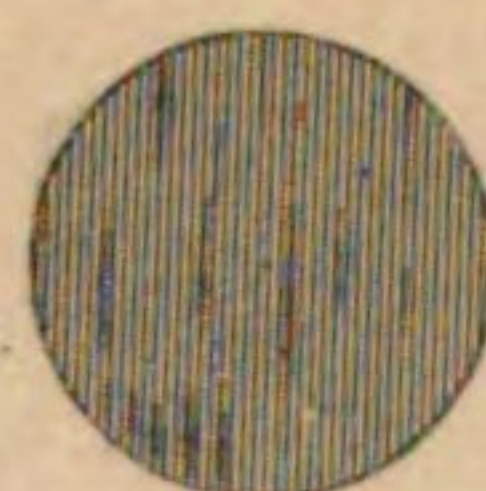
Nº 1.



Nº 2.



Nº 3.



Nº 4.

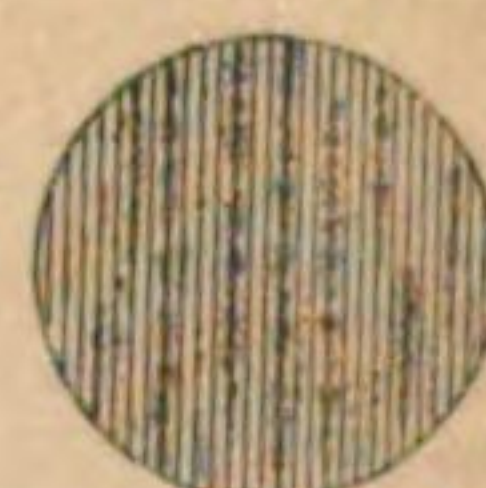


Fig. 24.



Fig. 25.

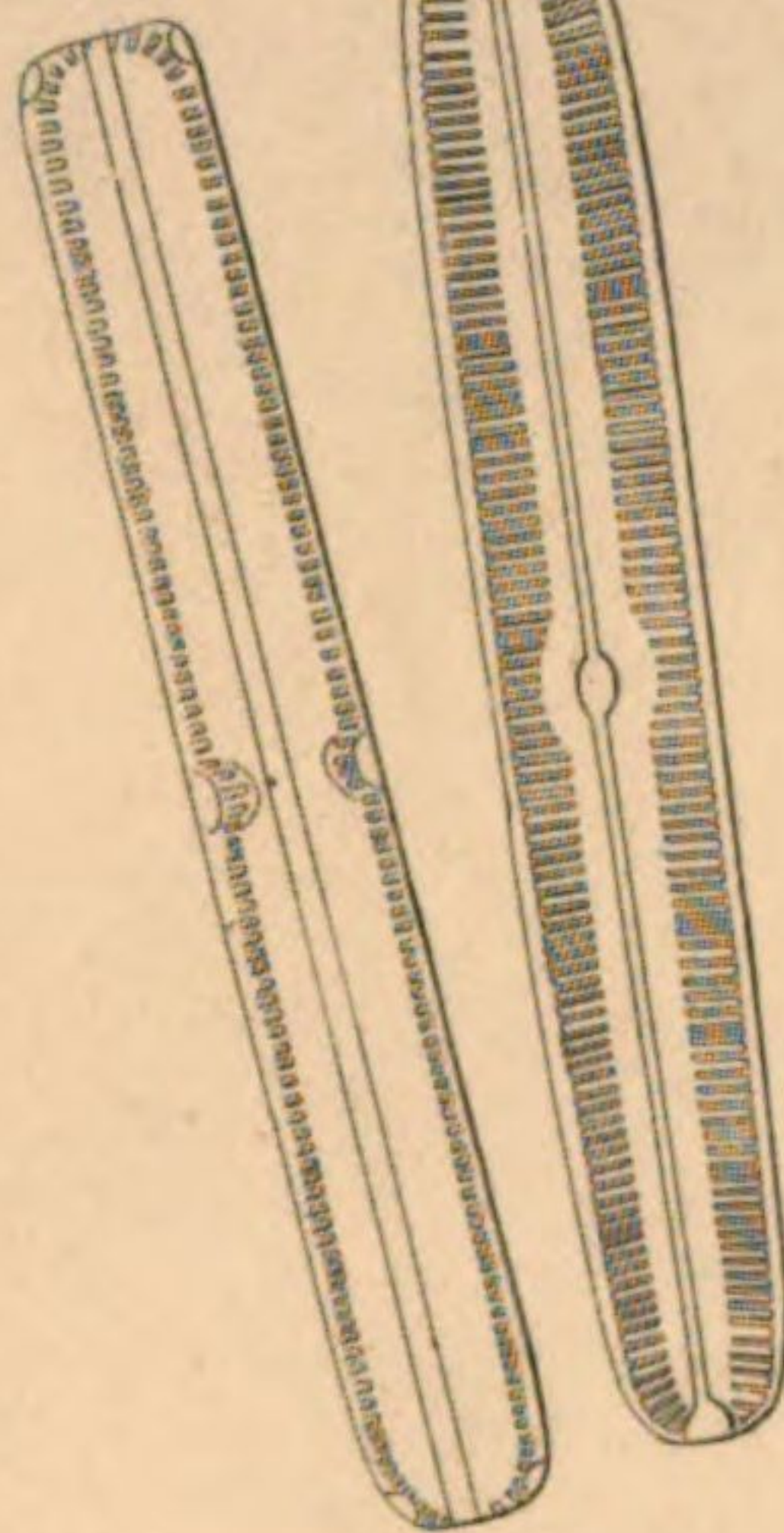
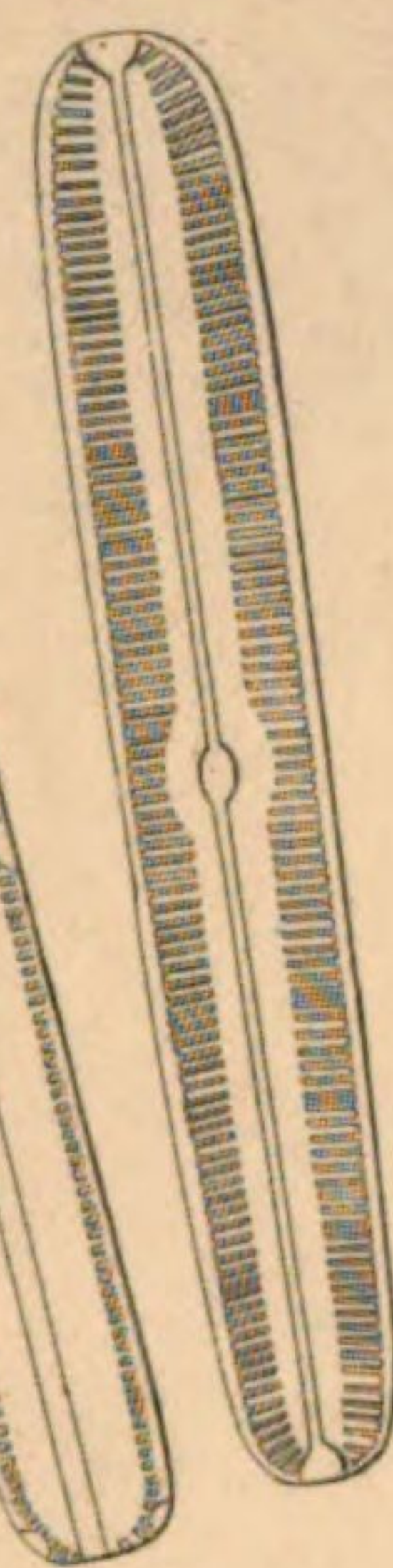


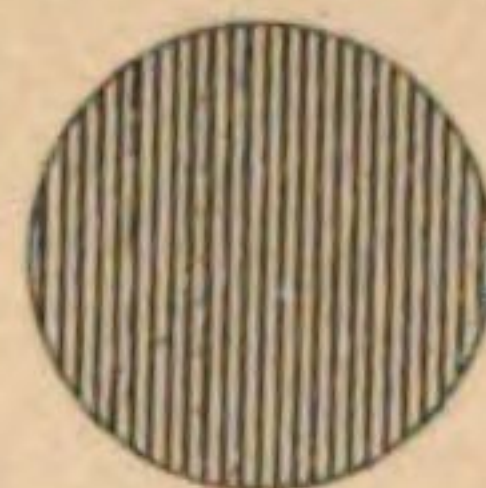
Fig. 26.



Nº 5.



Nº 6.



Nº 7.

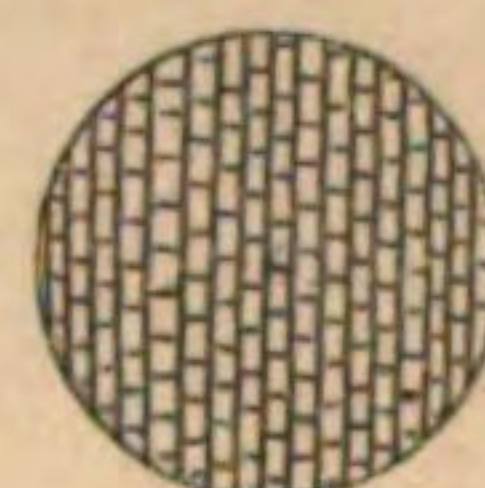


Fig. 28.

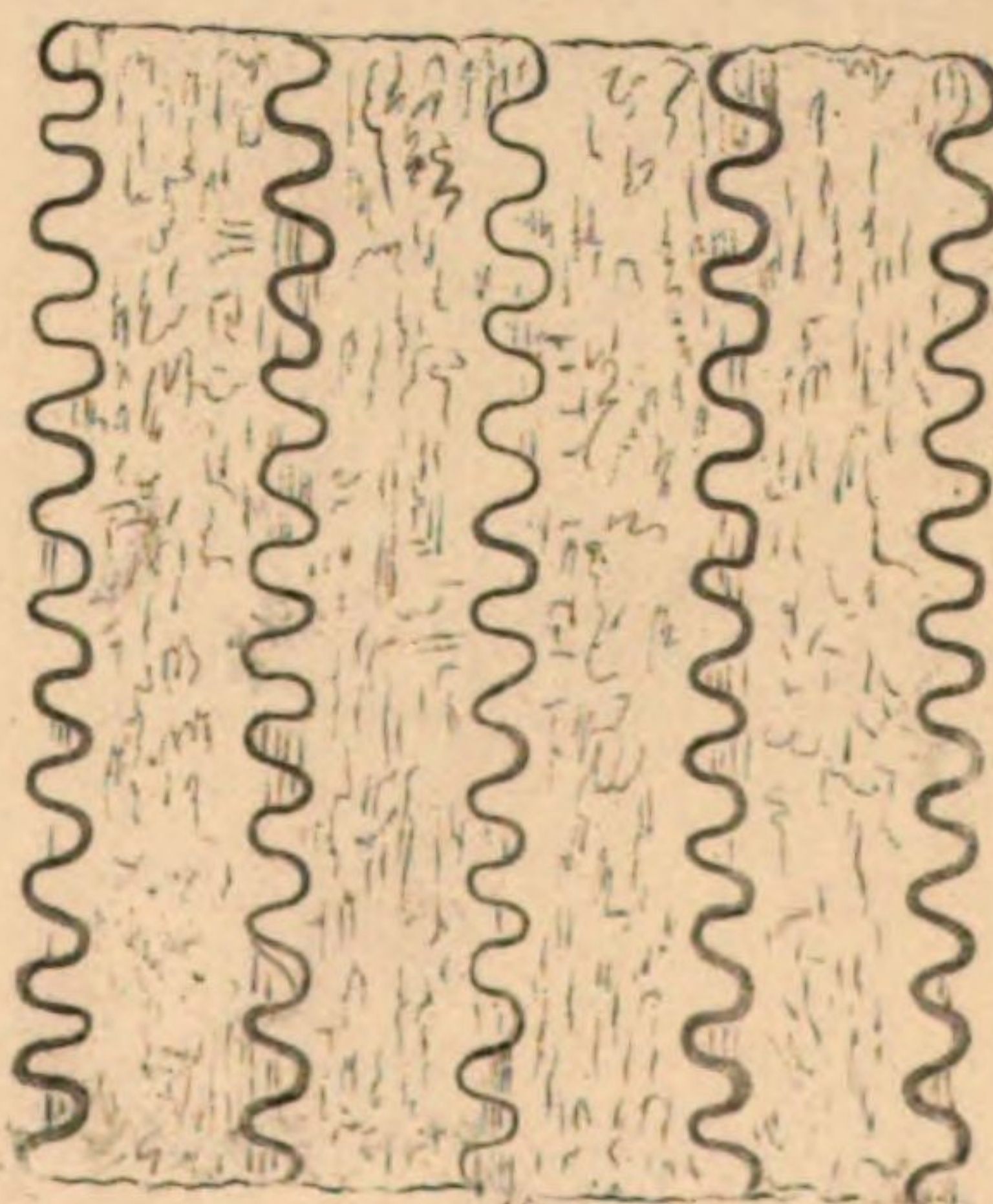


Fig. 30.



Fig. 31.



Fig. 27.

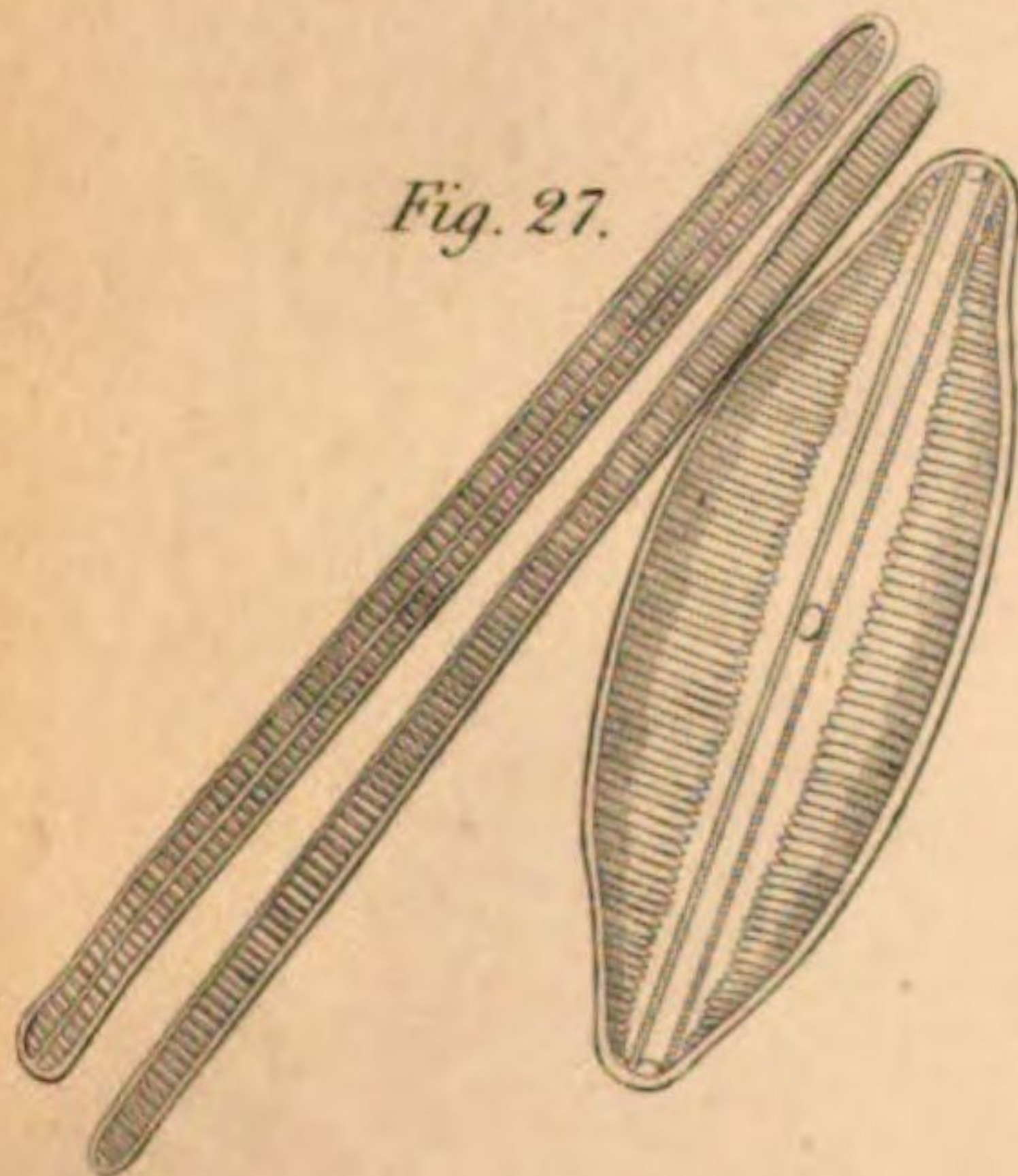
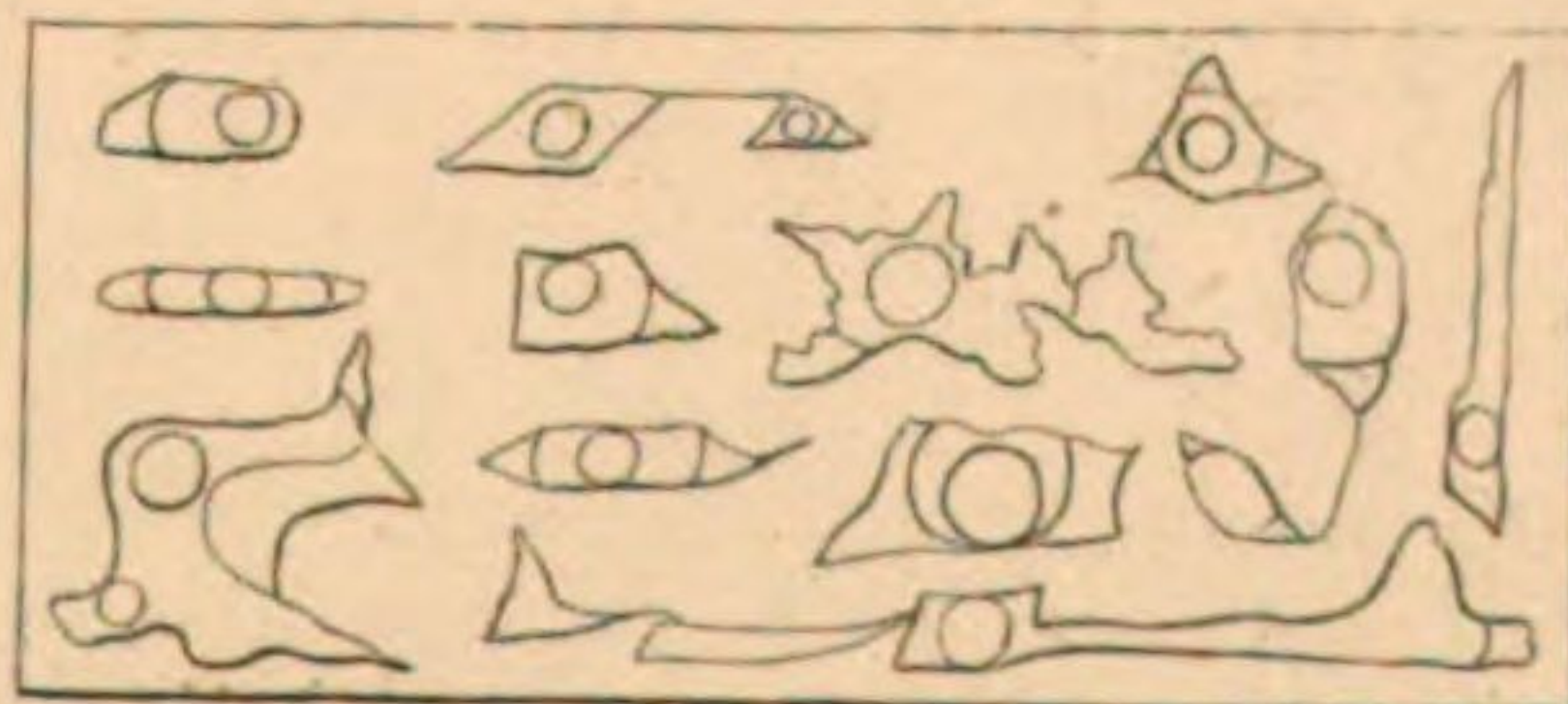


Fig. 29.



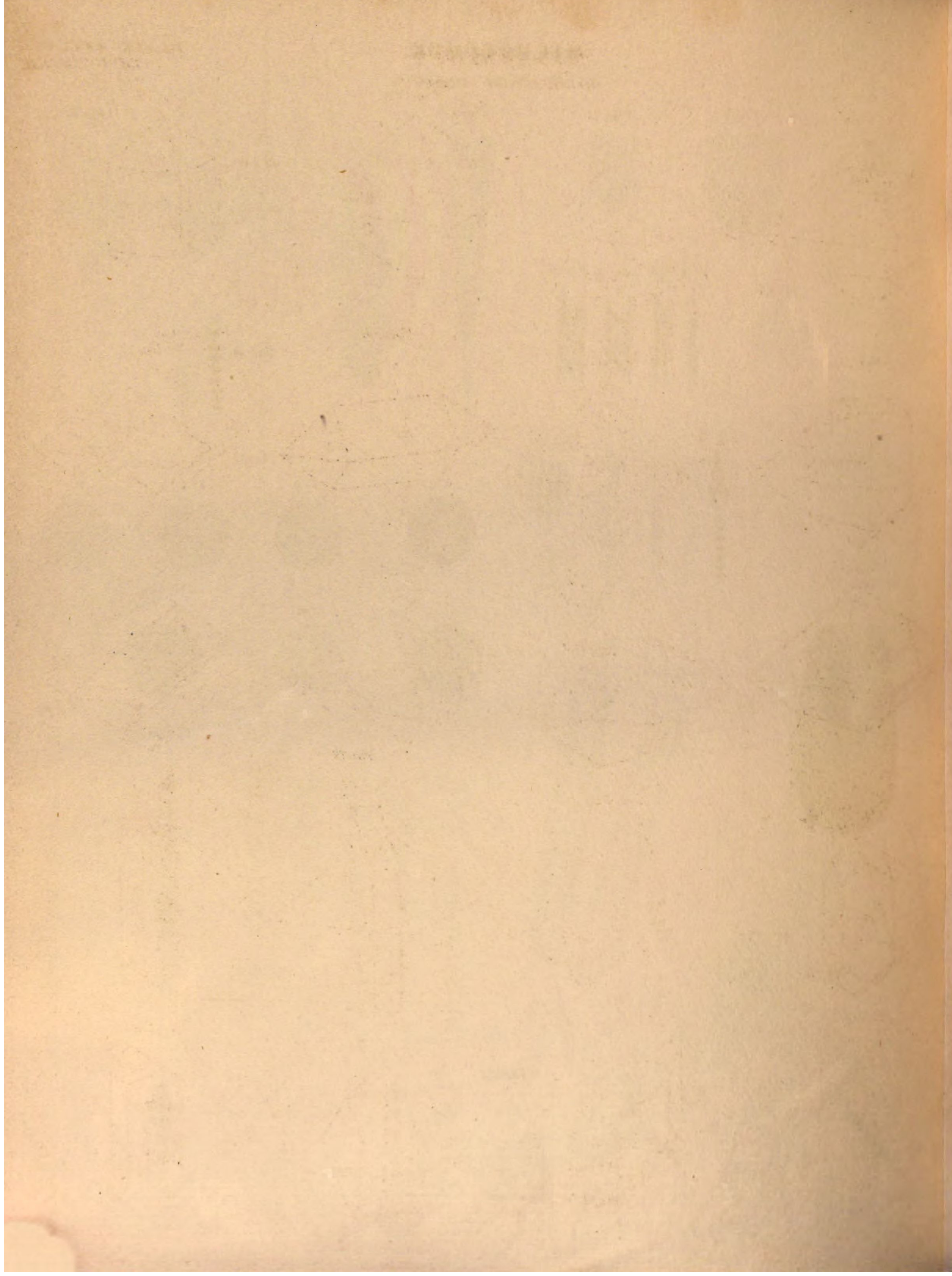


Fig. 27.

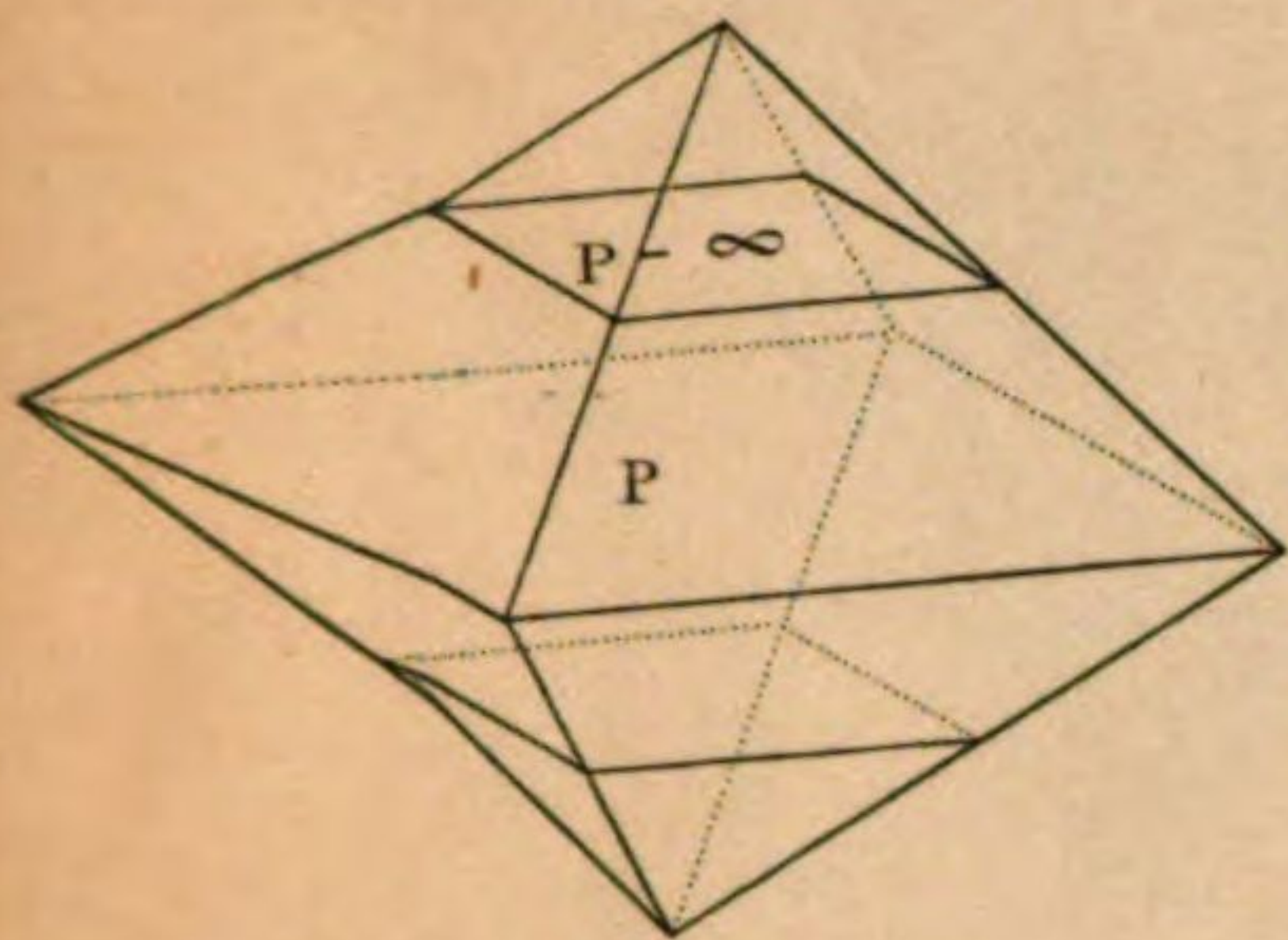


Fig. 28.

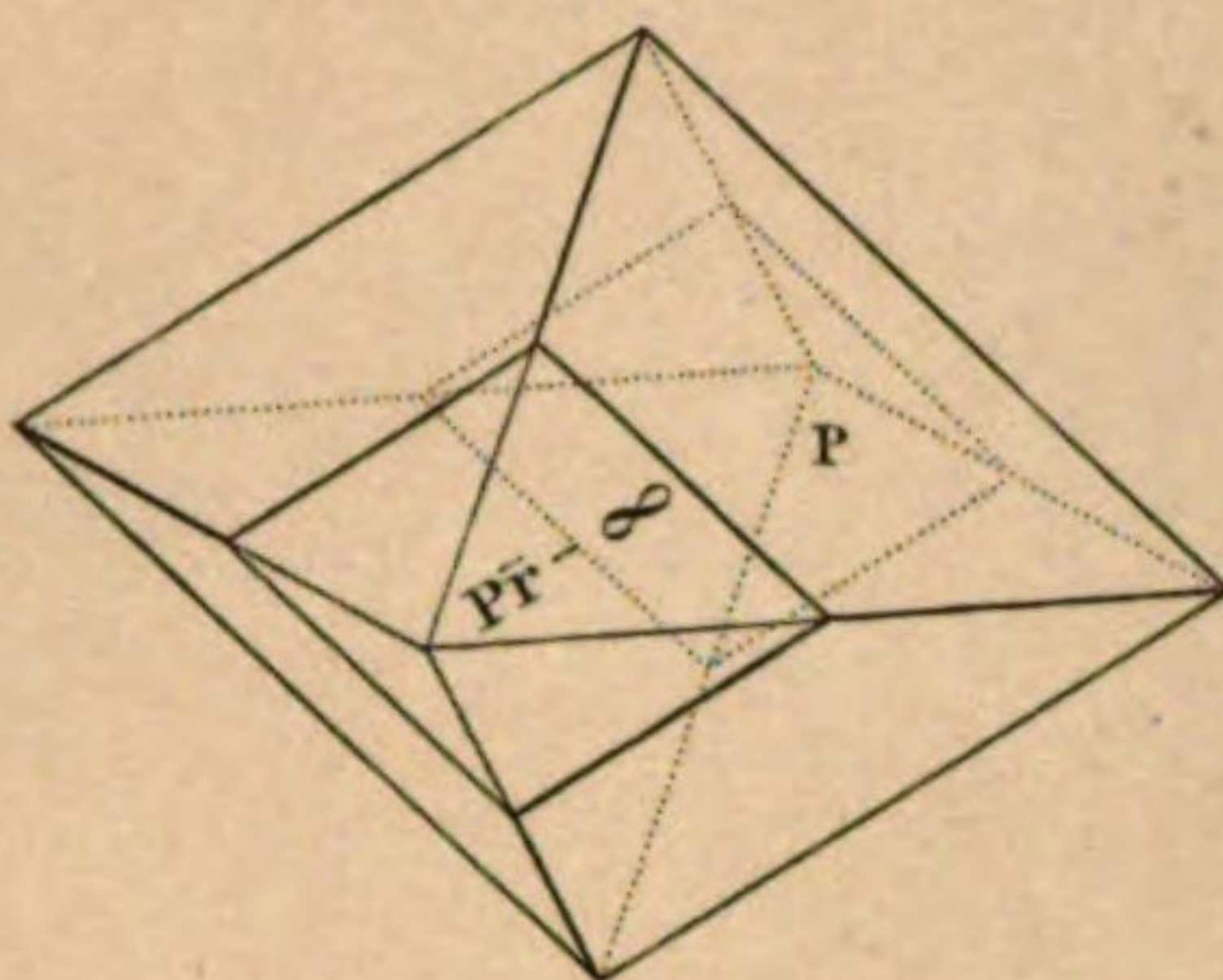


Fig. 29.

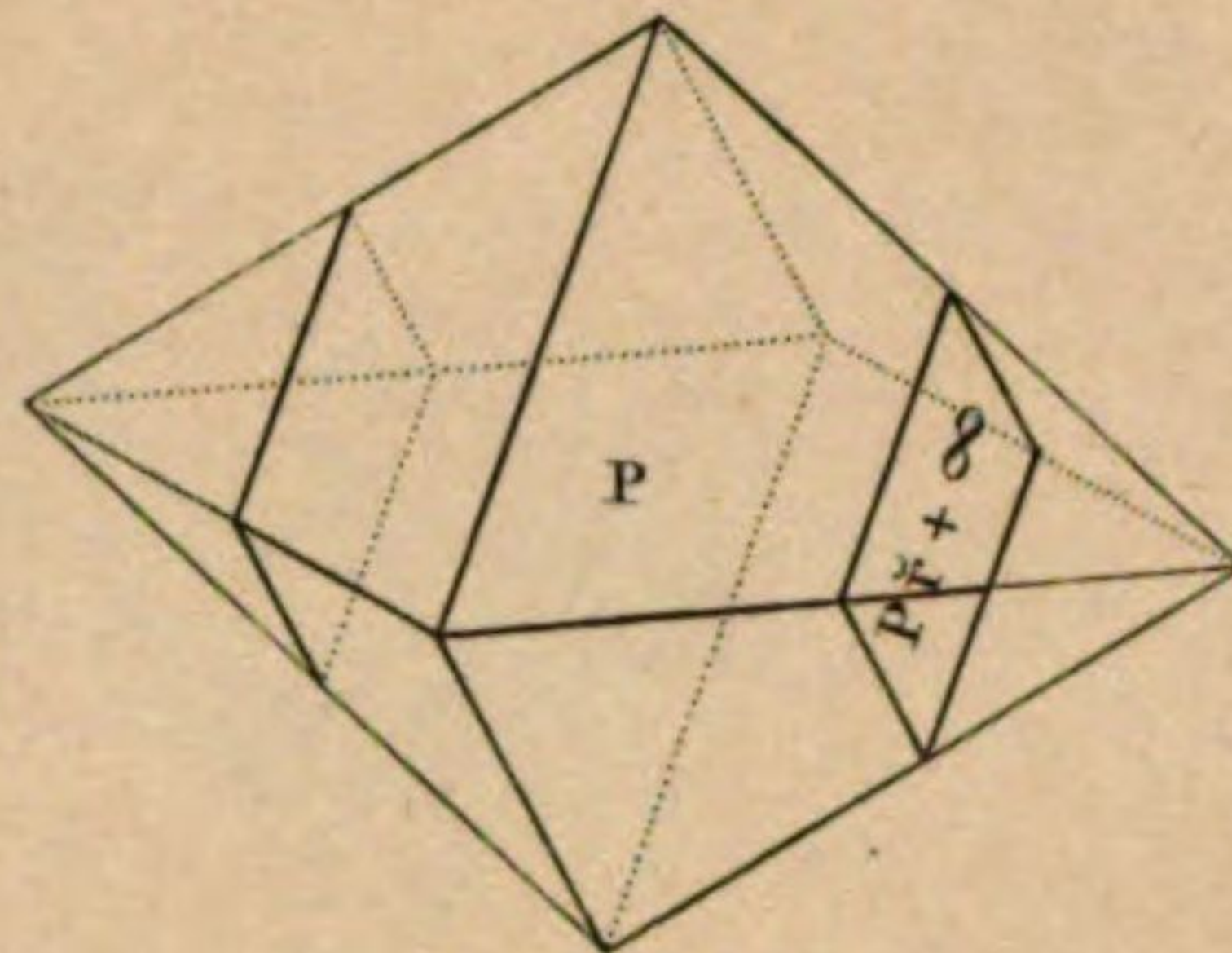


Fig. 30.

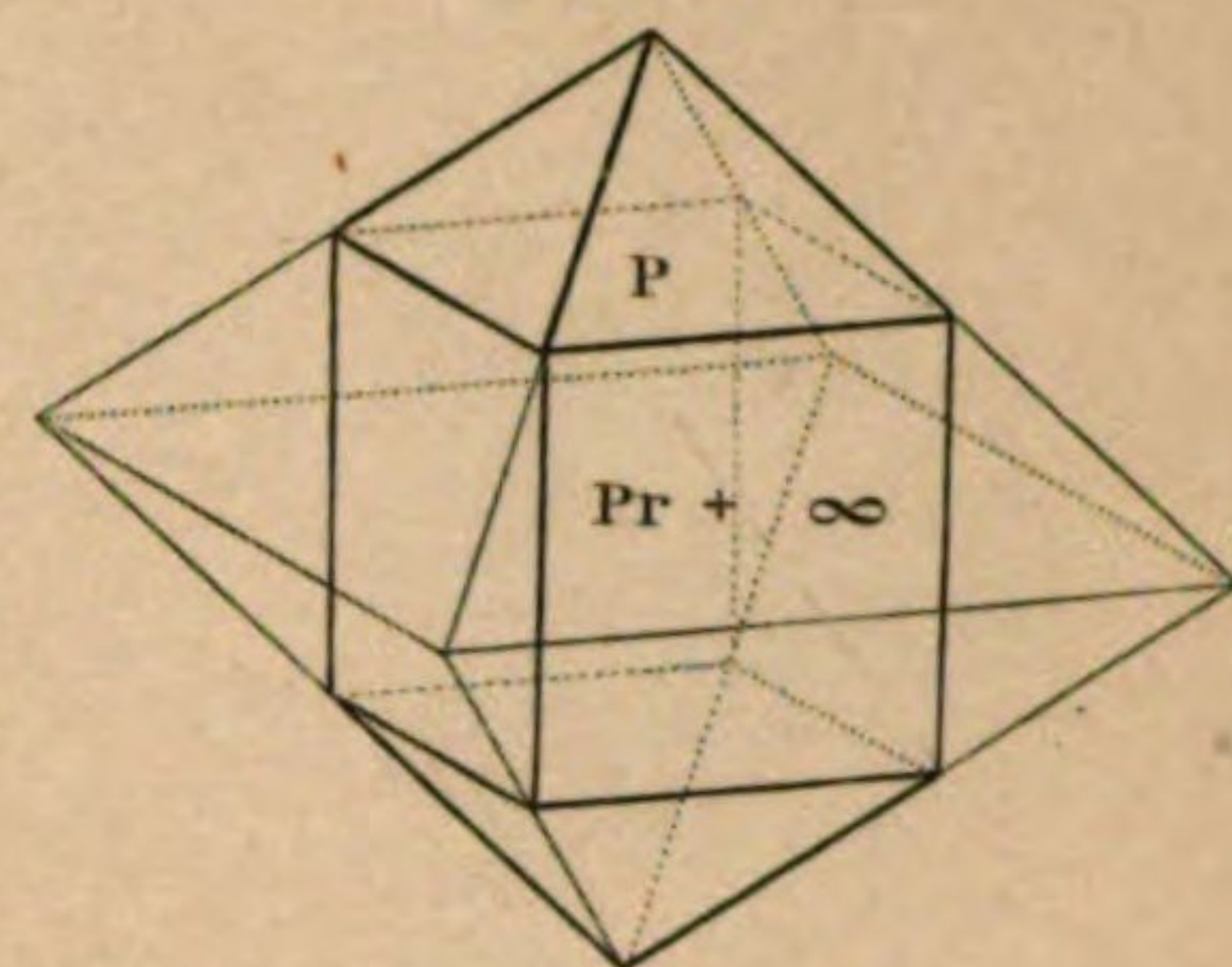


Fig. 31.

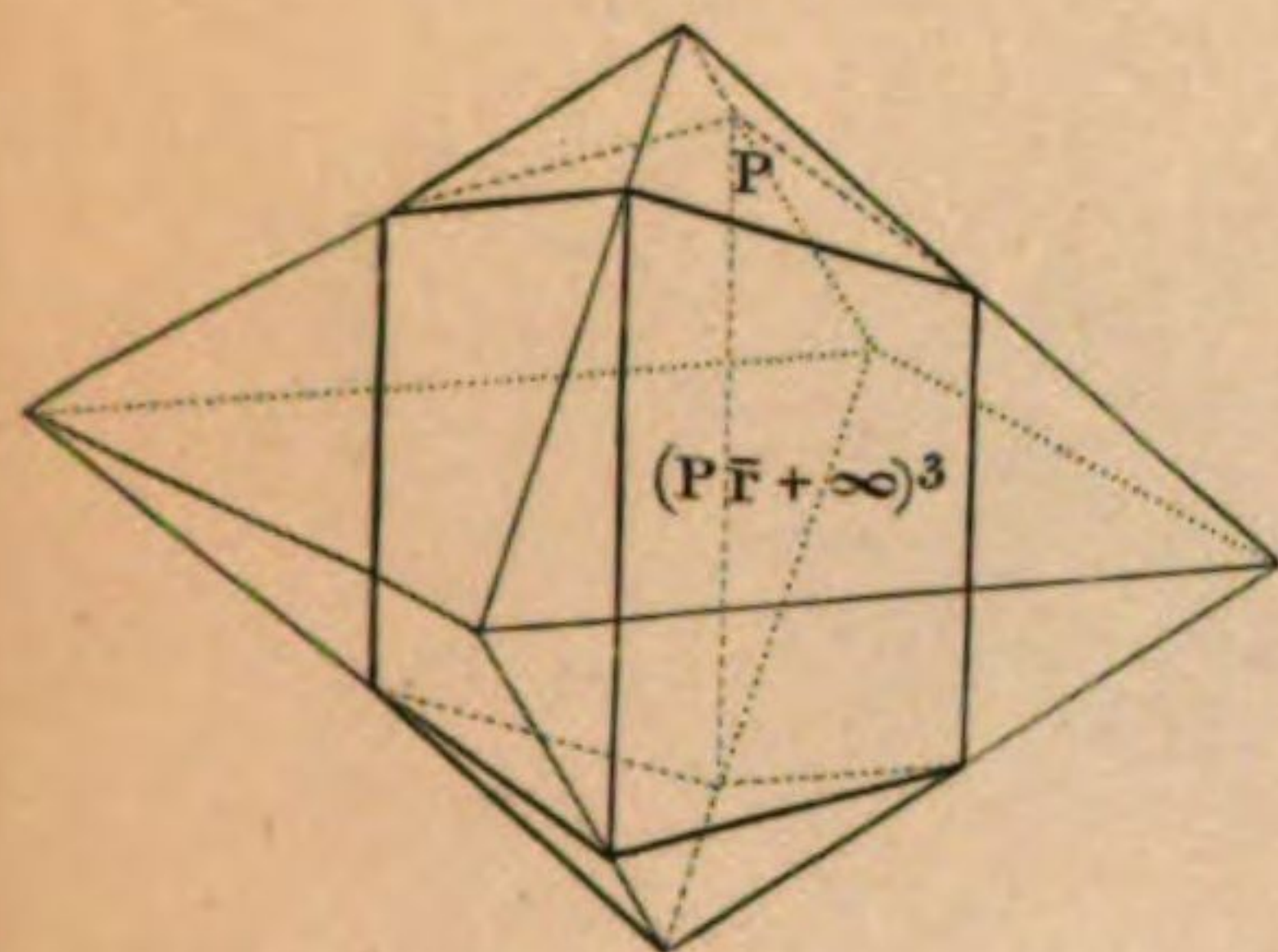


Fig. 32.

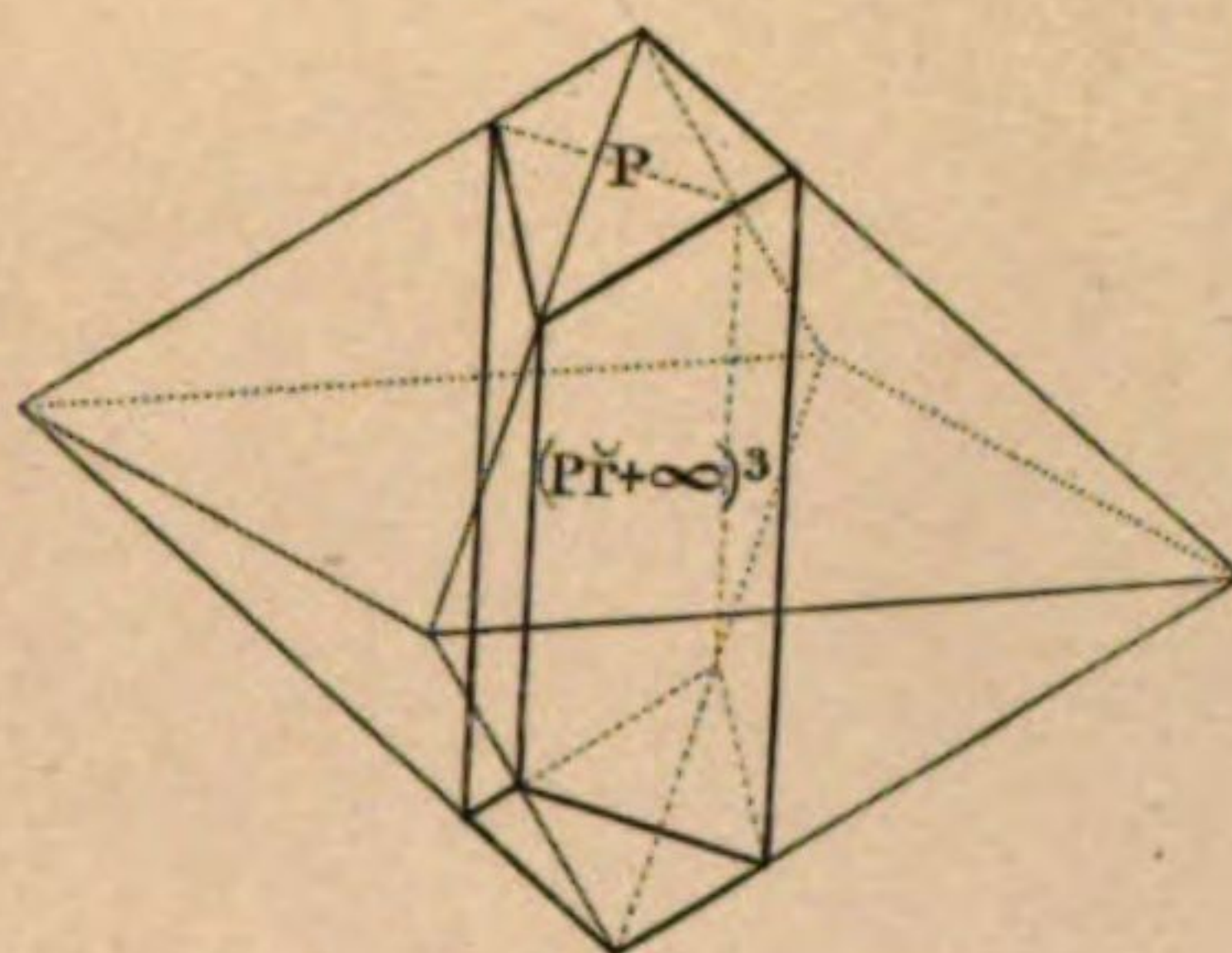


Fig. 33.

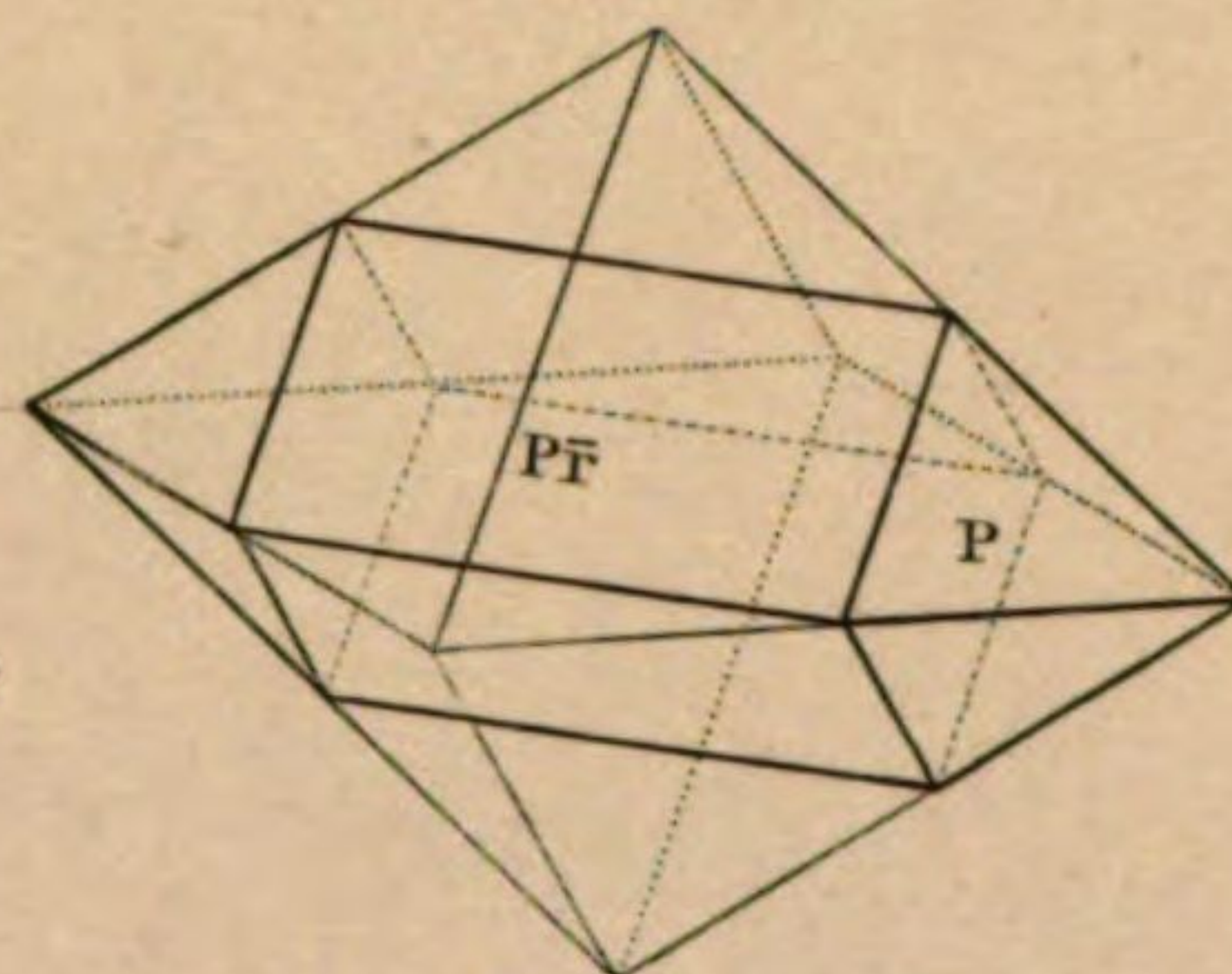


Fig. 34.

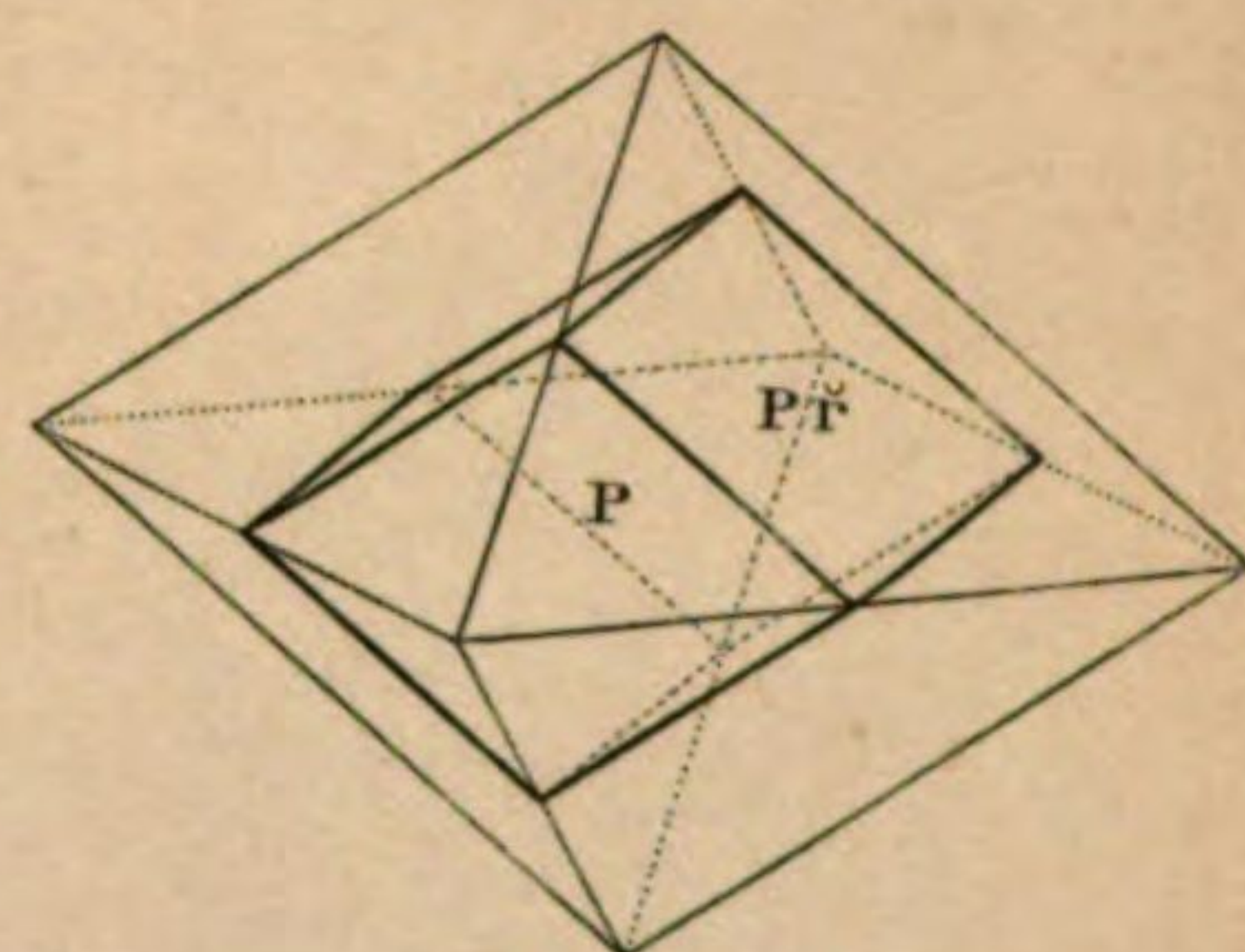


Fig. 35.

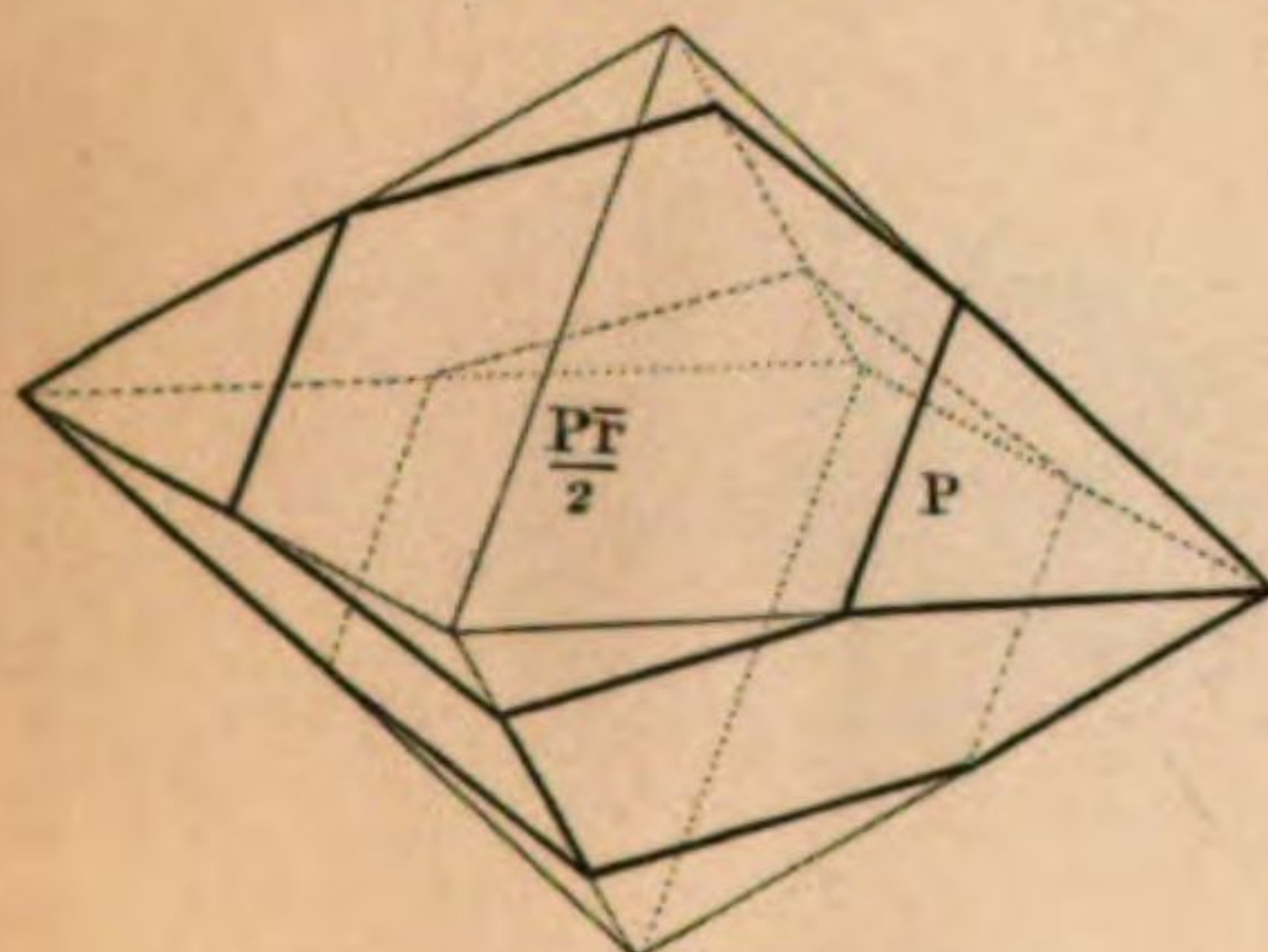


Fig. 36.

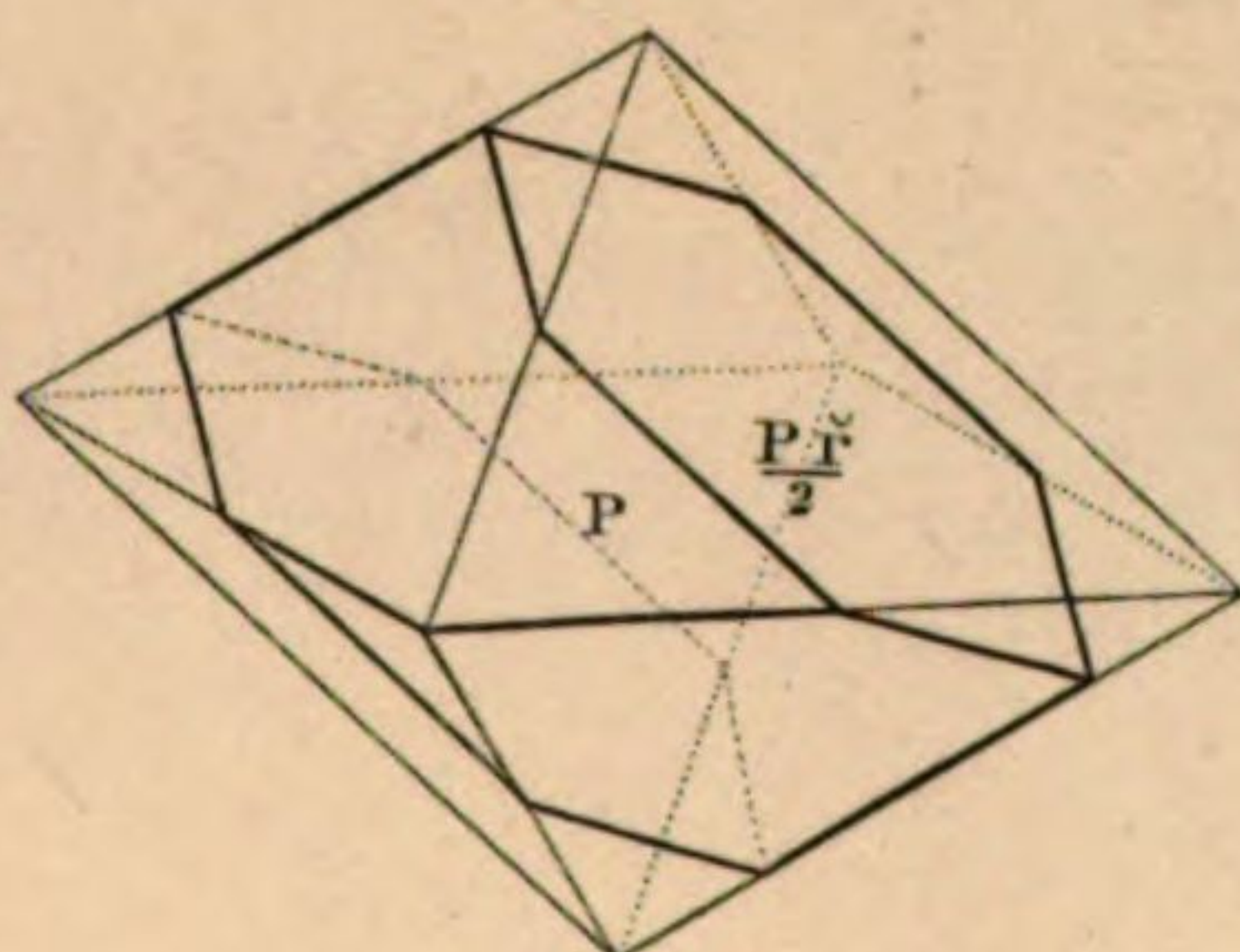


Fig. 37.

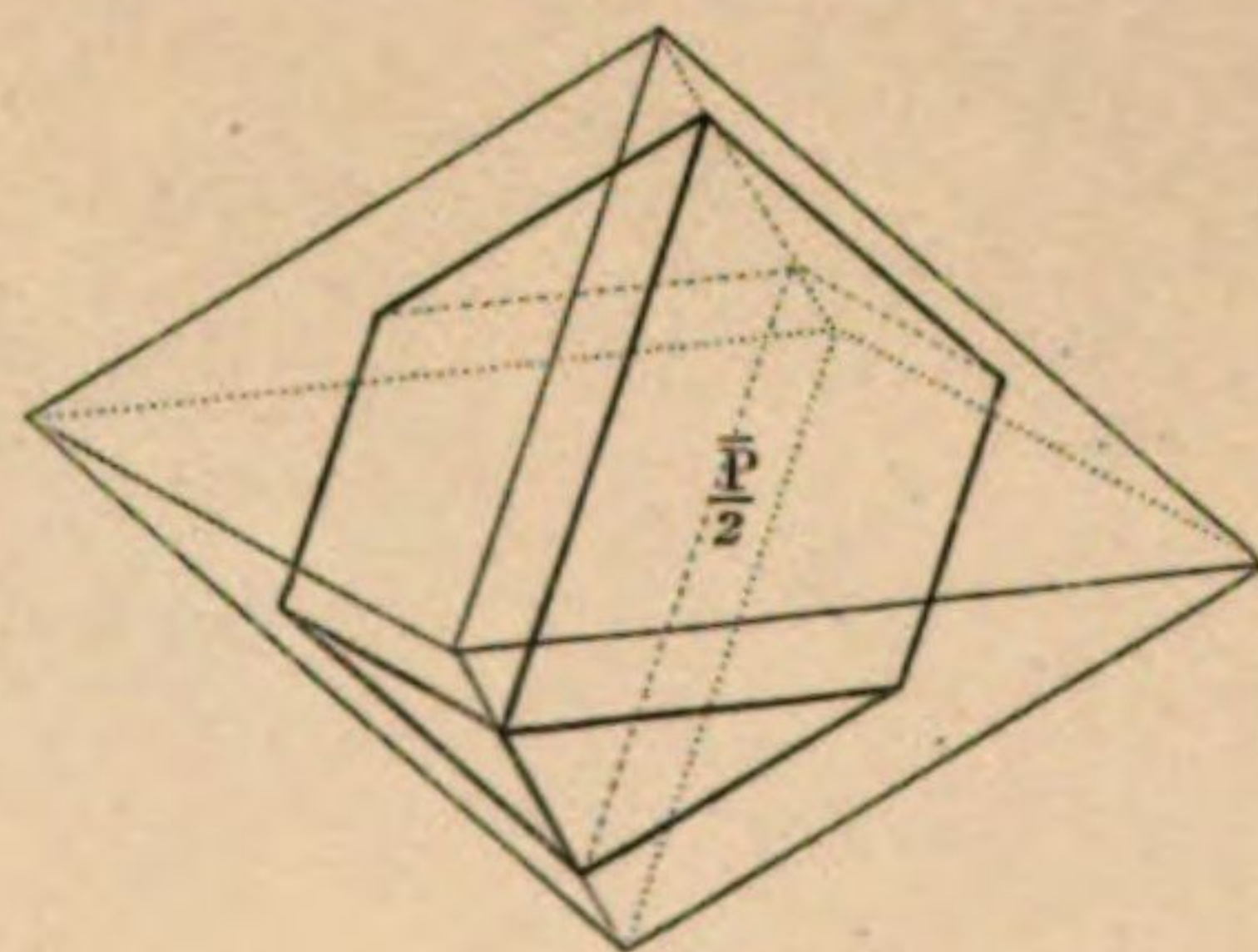


Fig. 38.

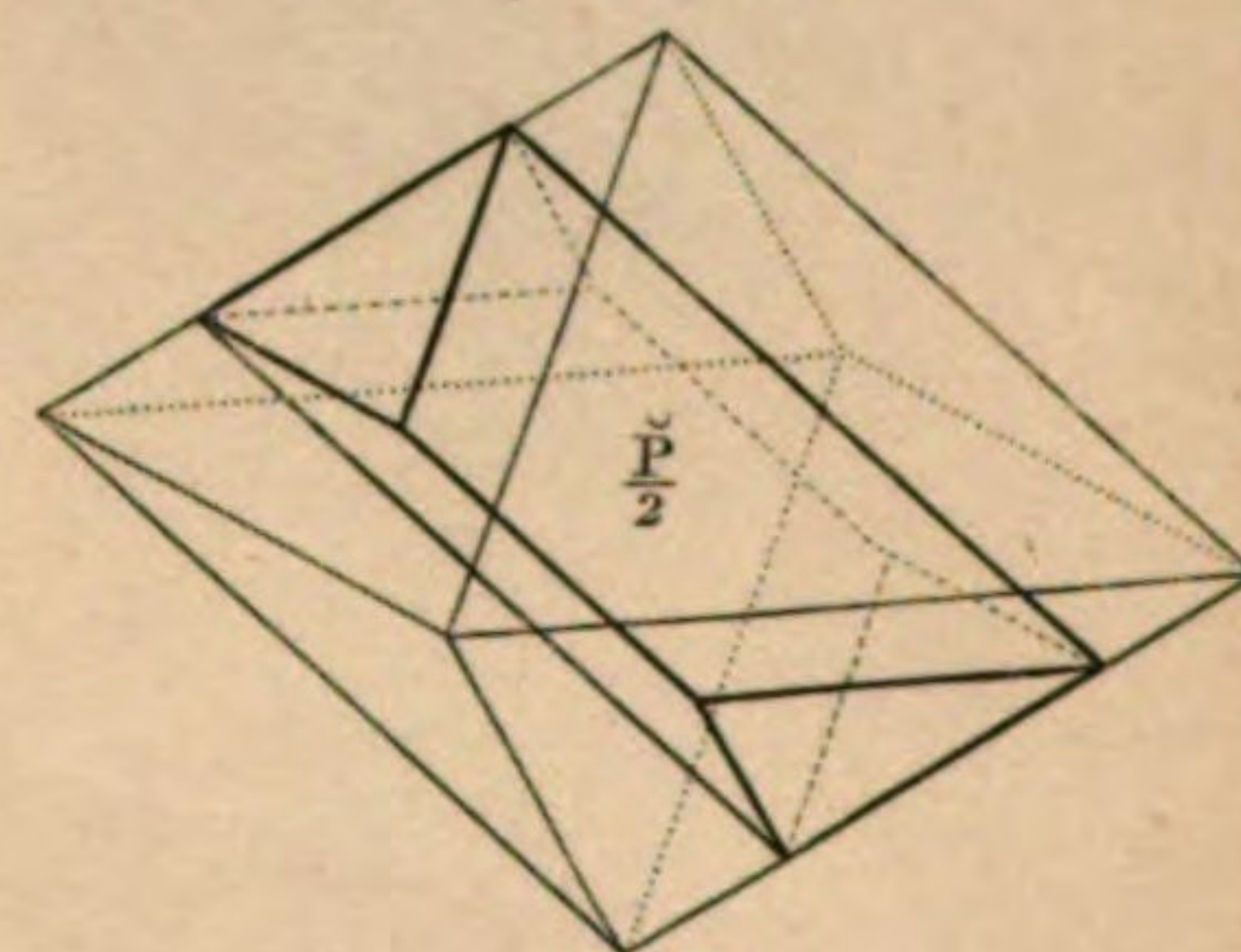


Fig. 39.

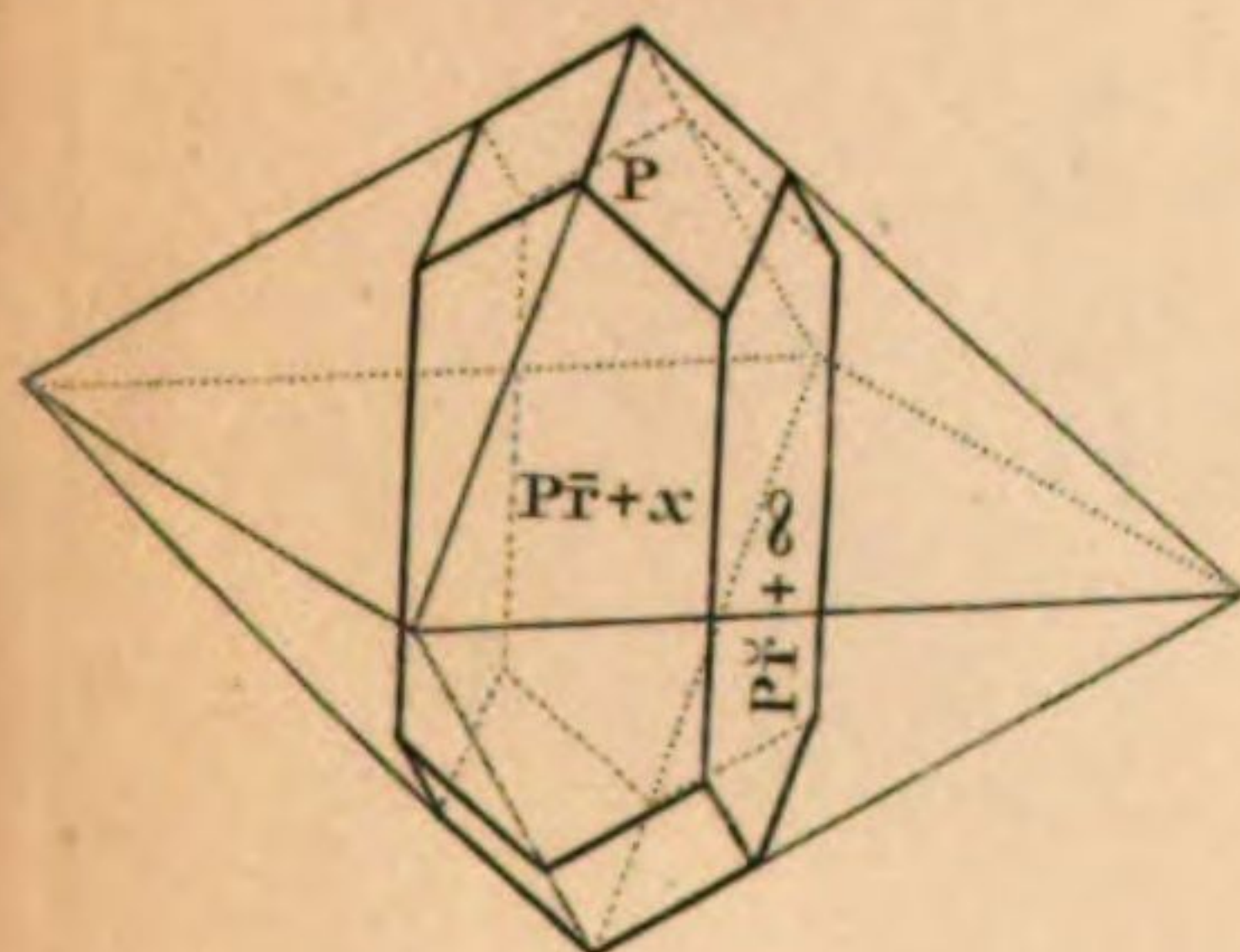


Fig. 40.

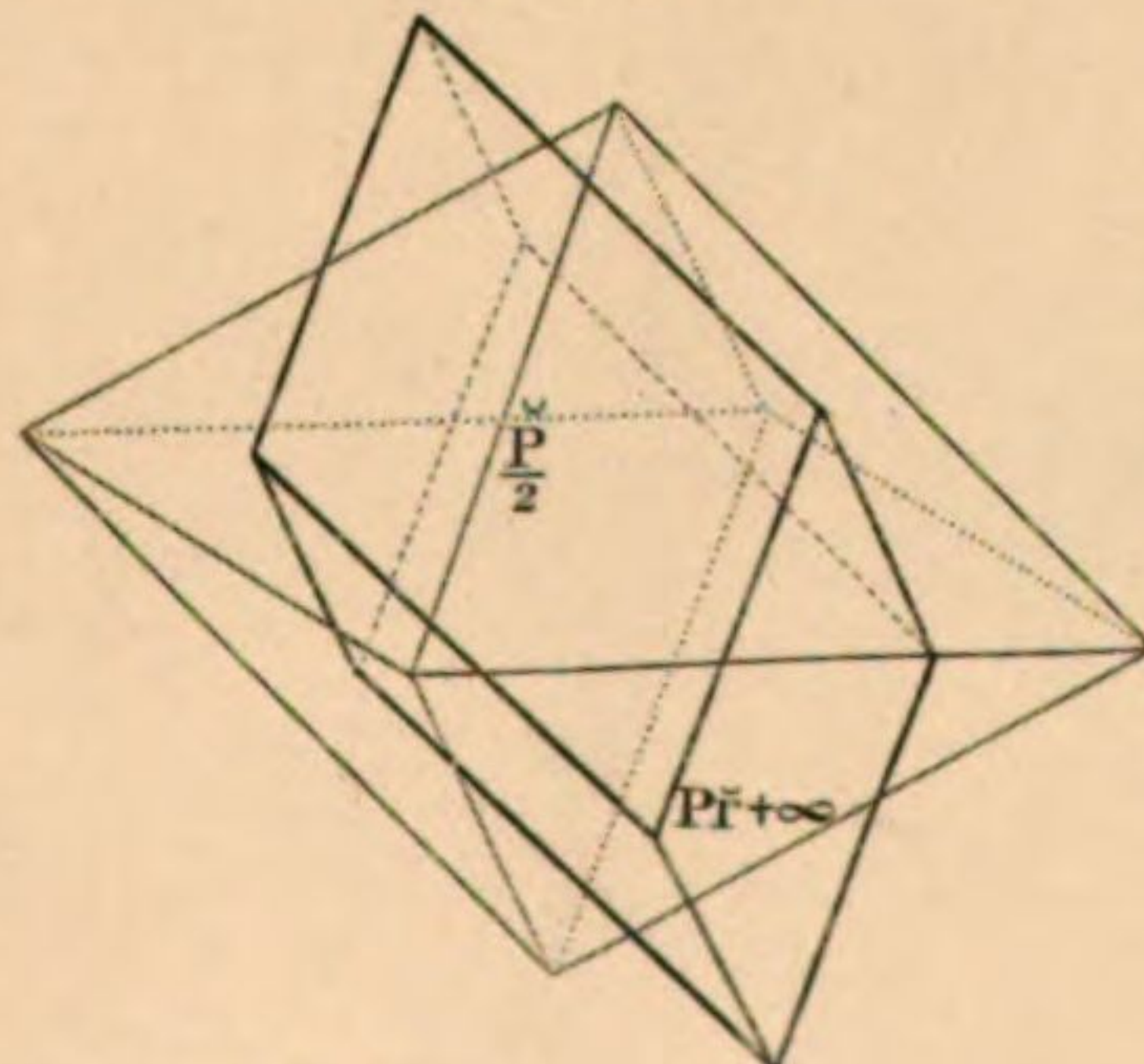


Fig. 41.

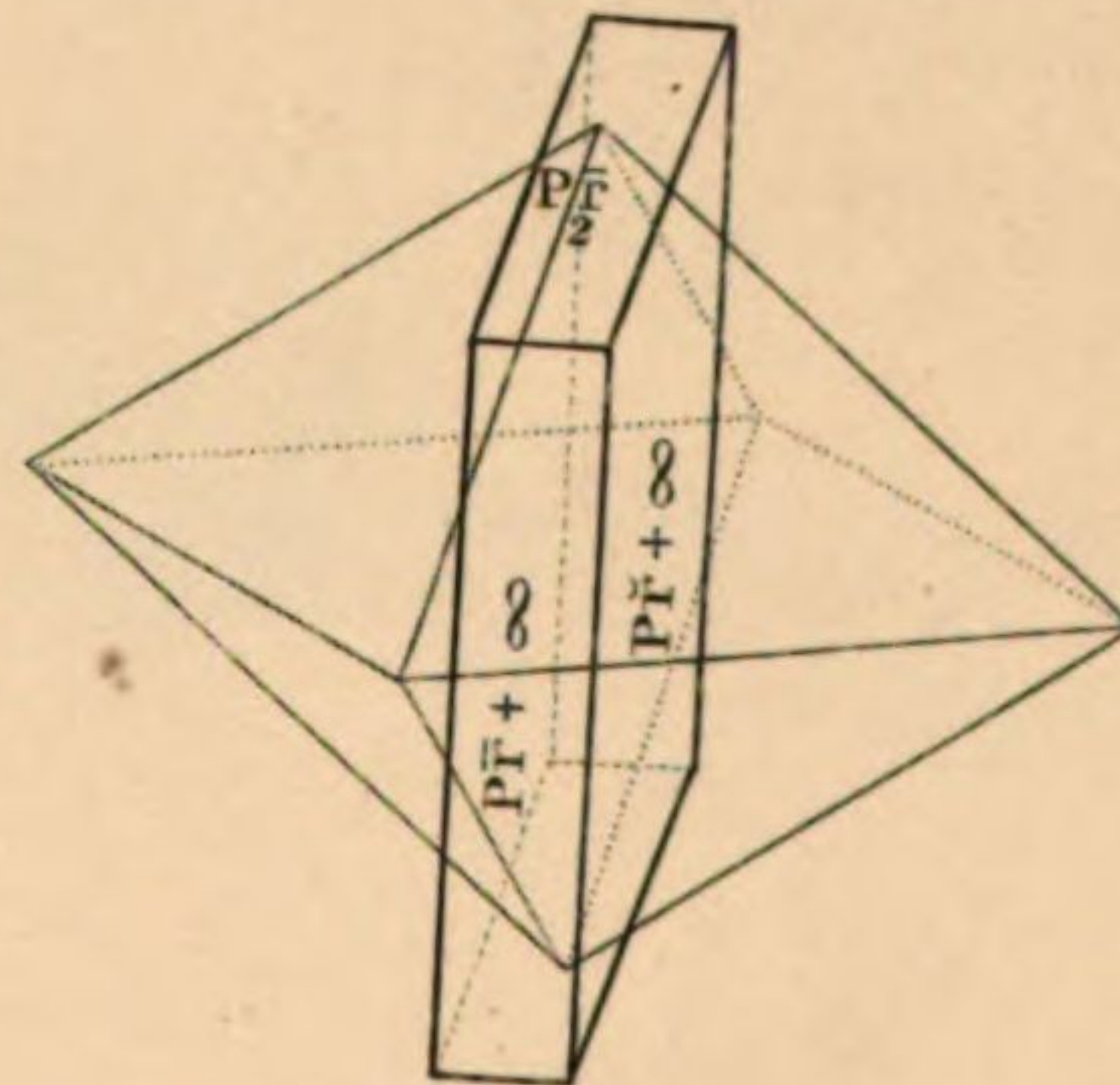


Fig. 42.

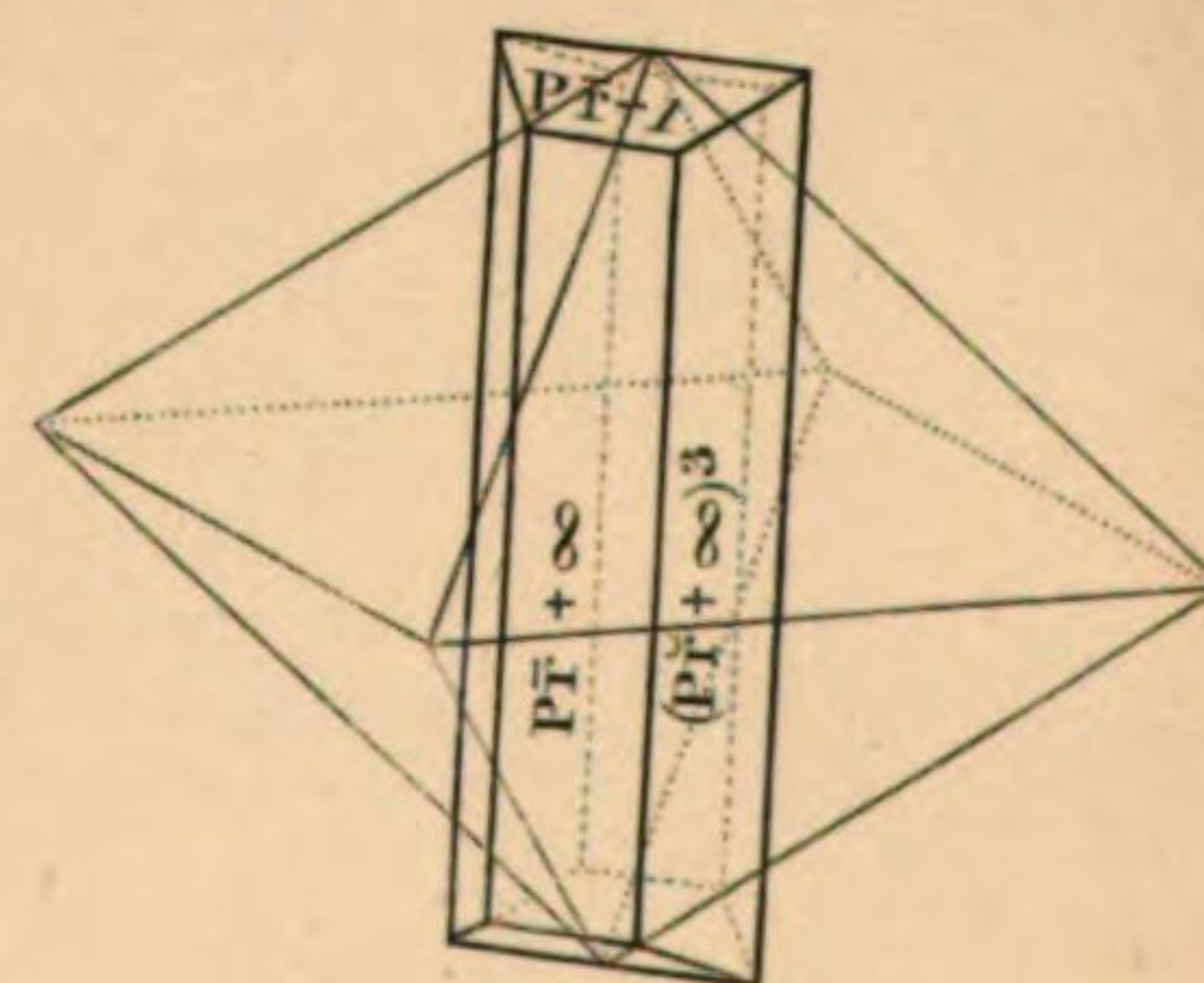


Fig. 43.

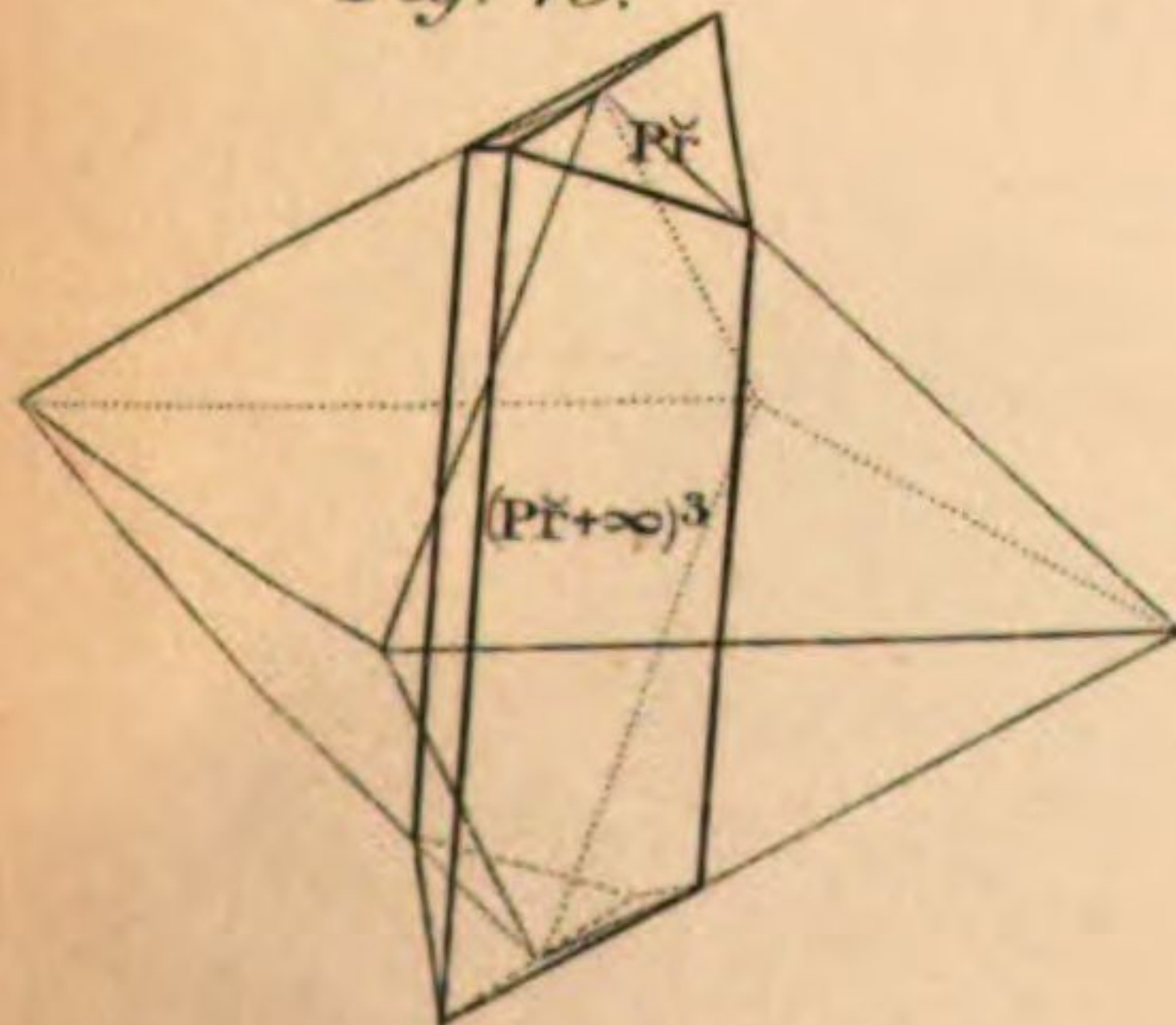


Fig. 44.

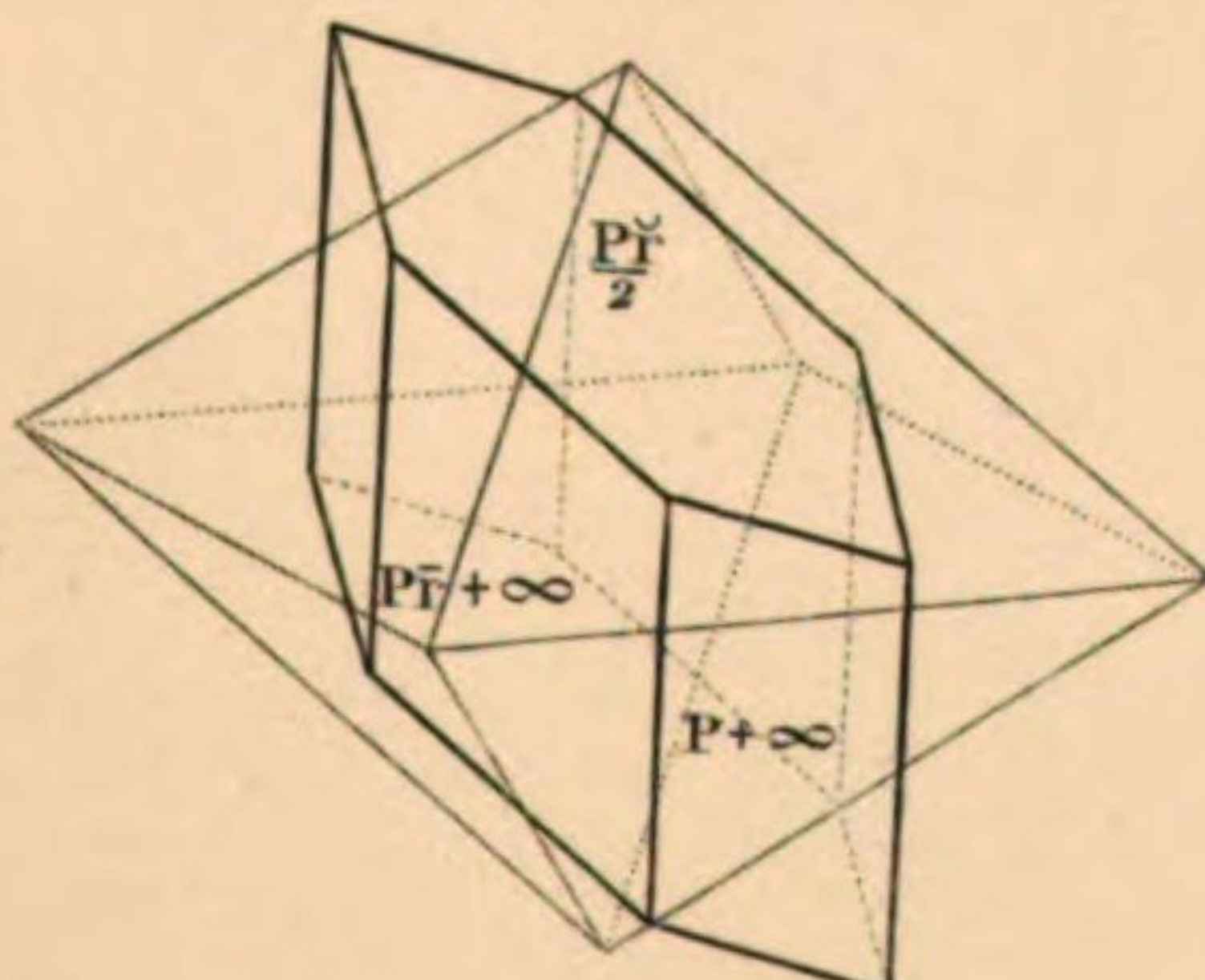


Fig. 45.

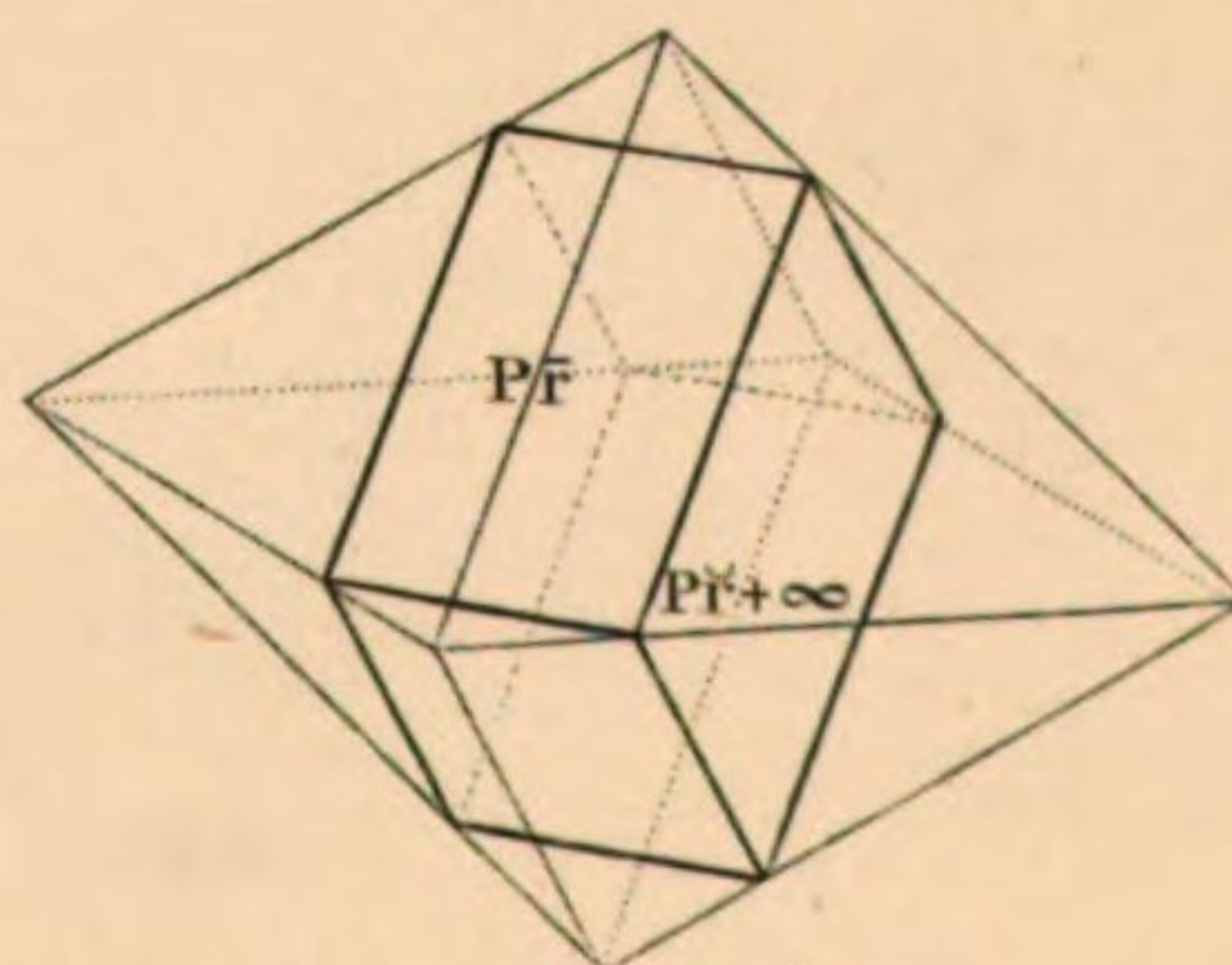
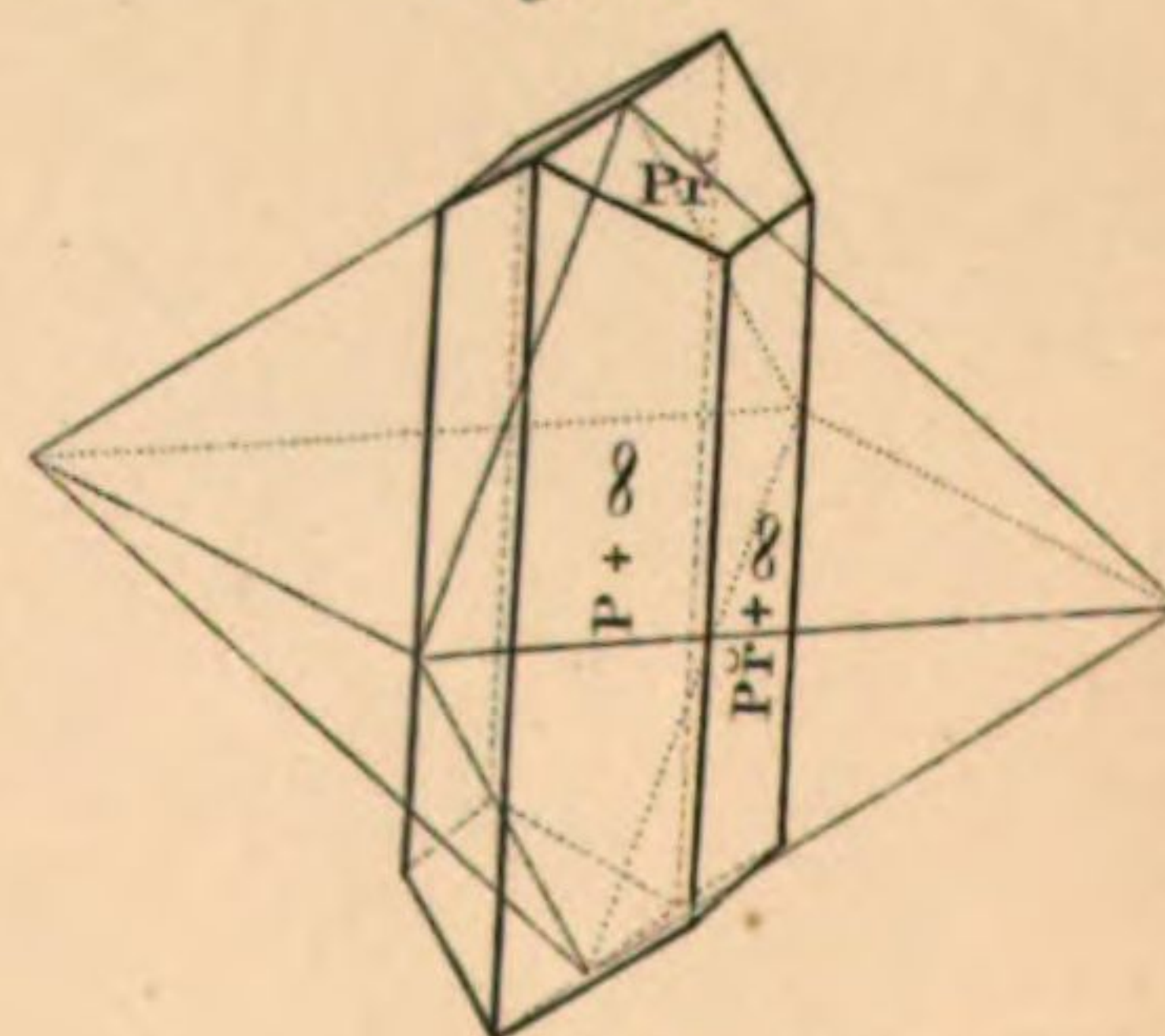


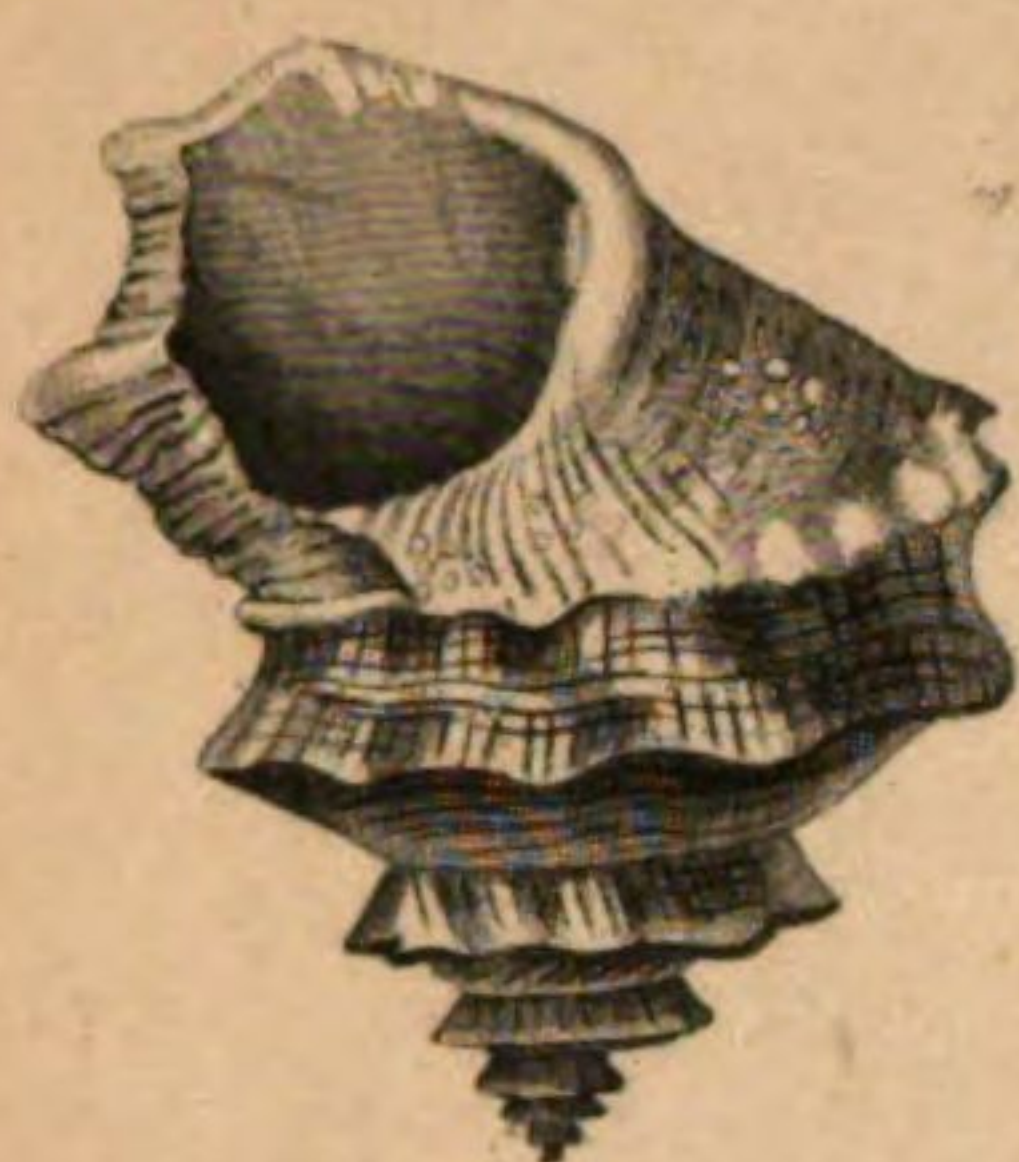
Fig. 46.



MOLLUSCA.

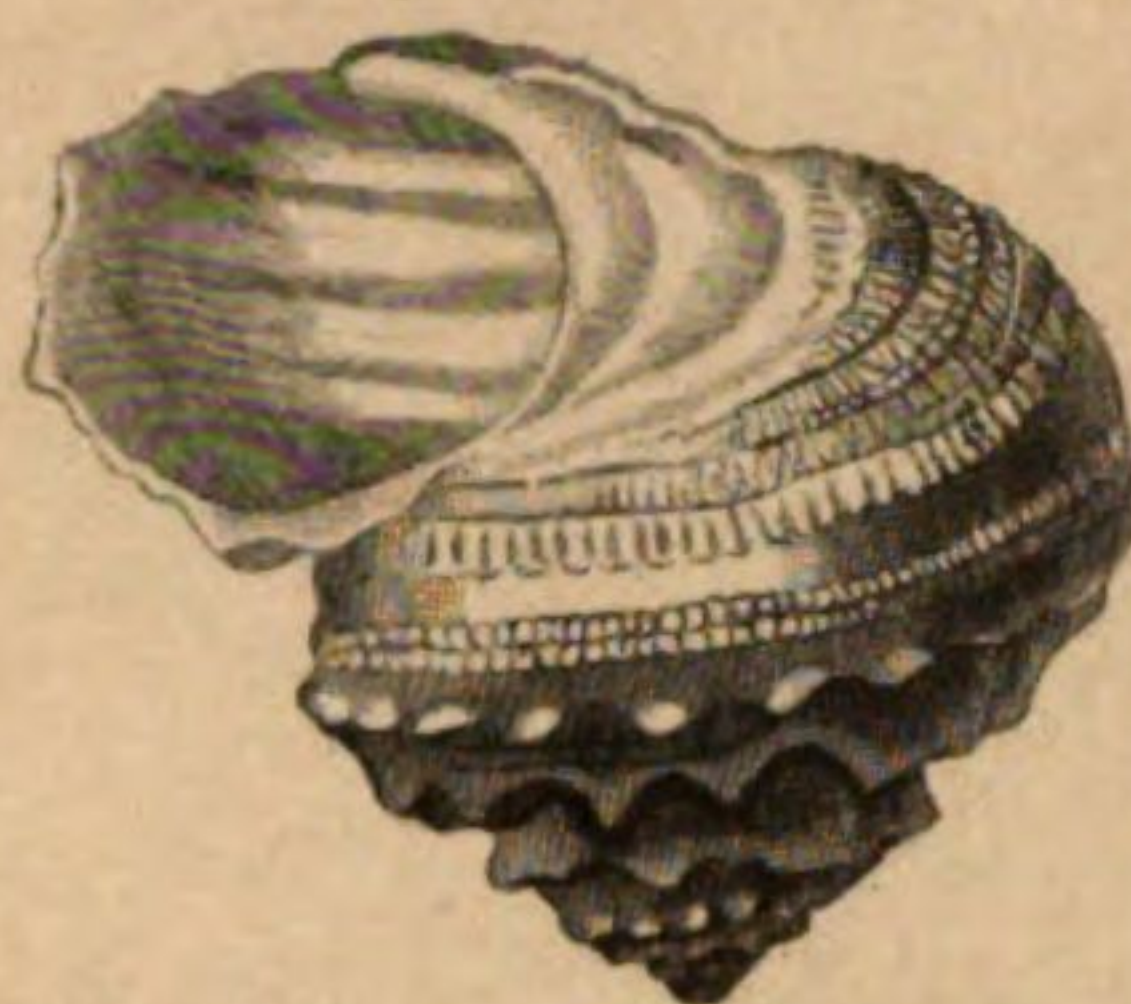
PLATE CCCLXI.

1.



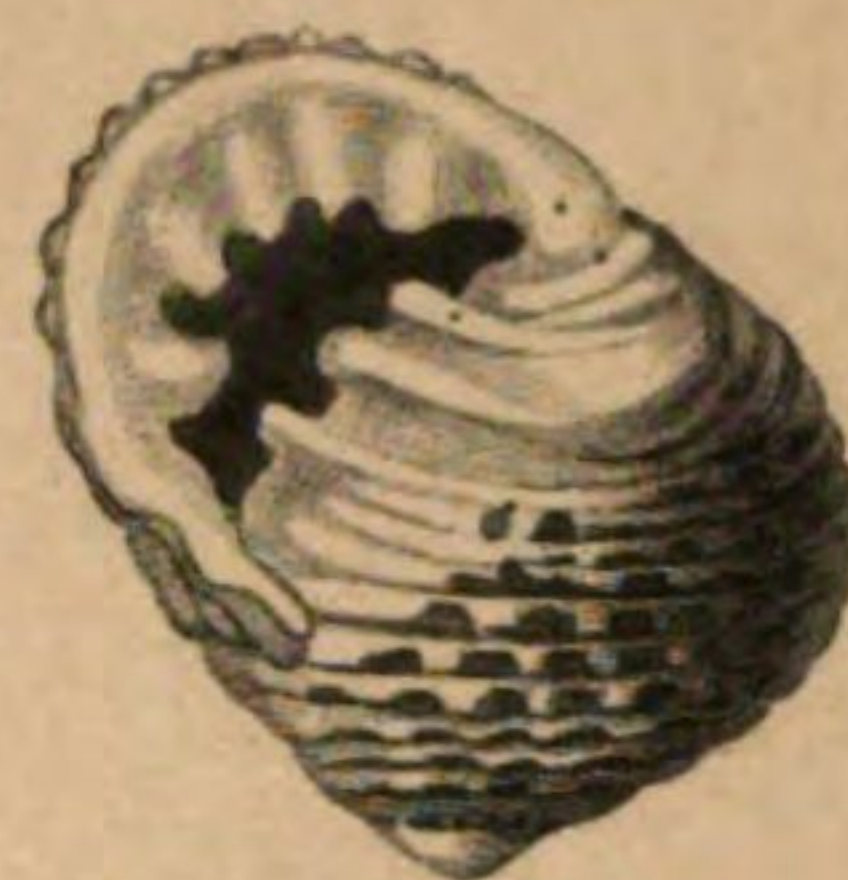
Trochus pagodus.

2.



Turbo rugosus.

3.



Natica plicata.

5.



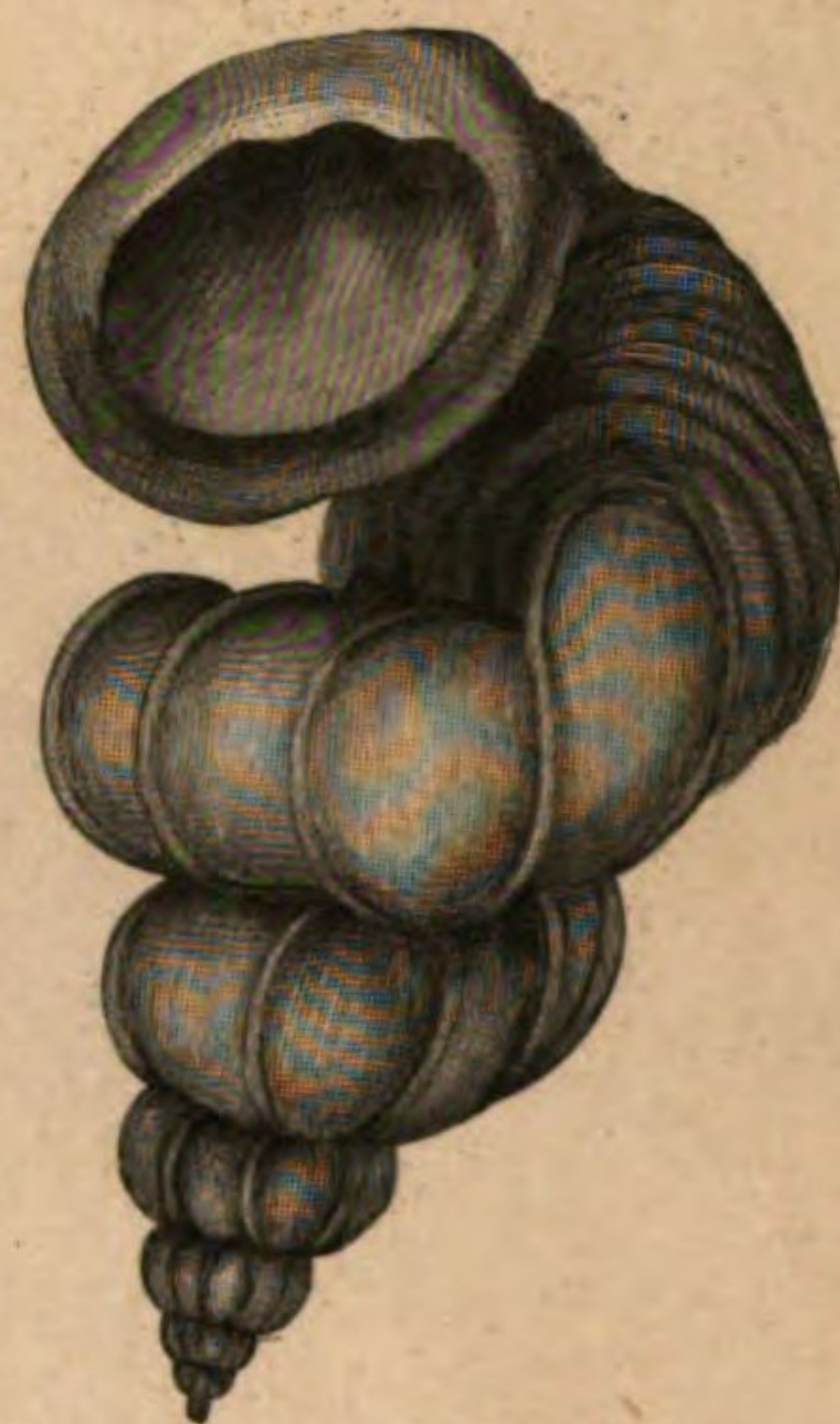
Delphinula calcar.

4.



Velutina laevigata.

7.



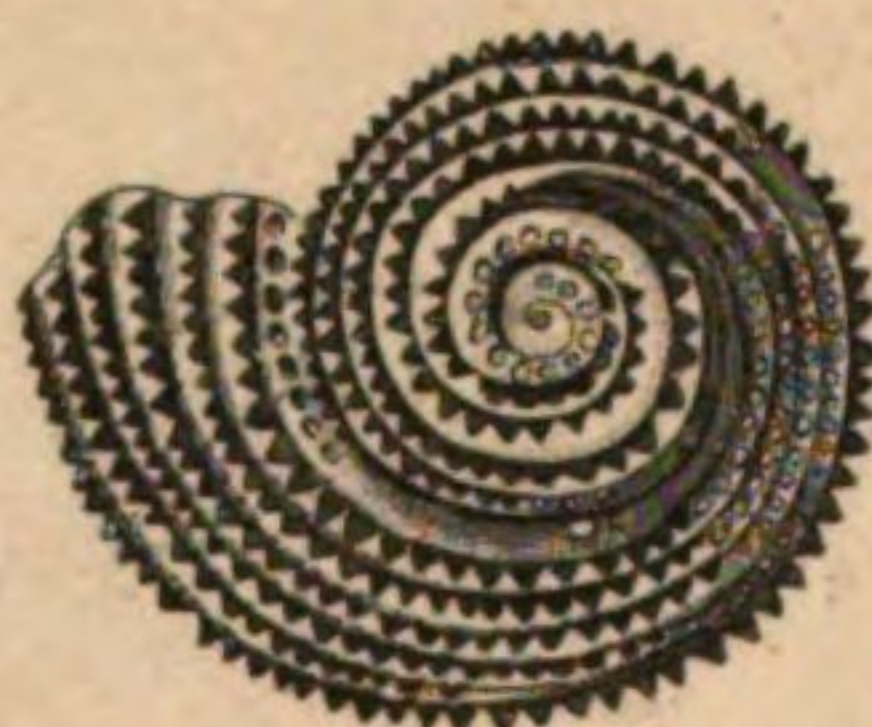
Scalaria pretiosa.

5.



Delphinula calcar.

6.



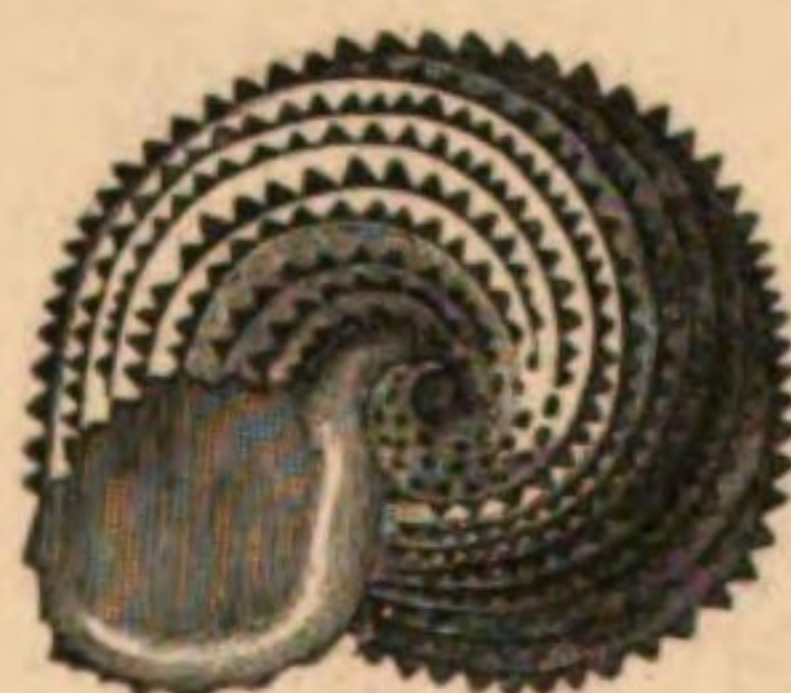
Delphinula lima.

8.



Solarium hybridum.

6.



Delphinula lima.

8.



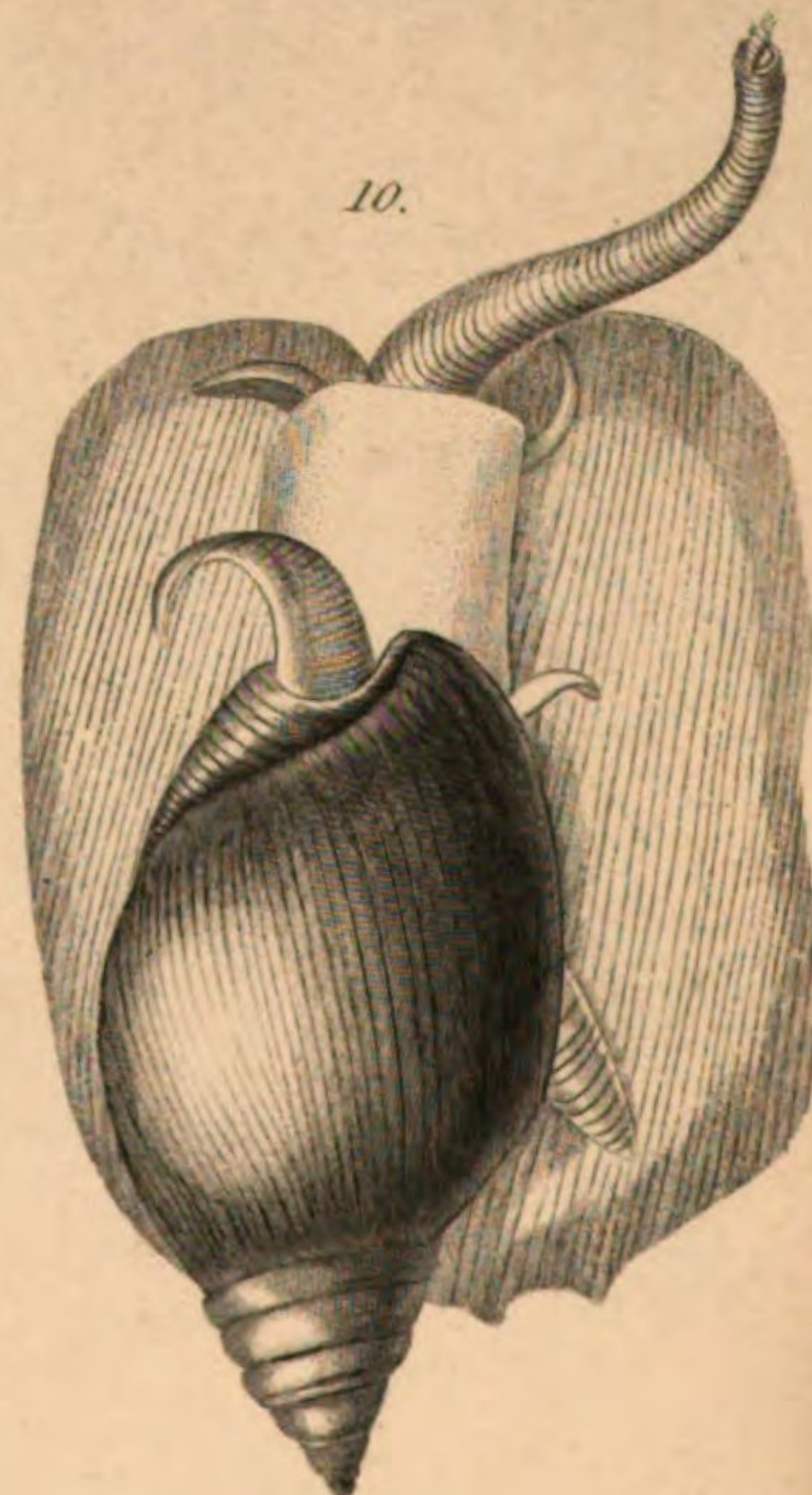
Solarium hybridum.

9.



Paludina vivipara.

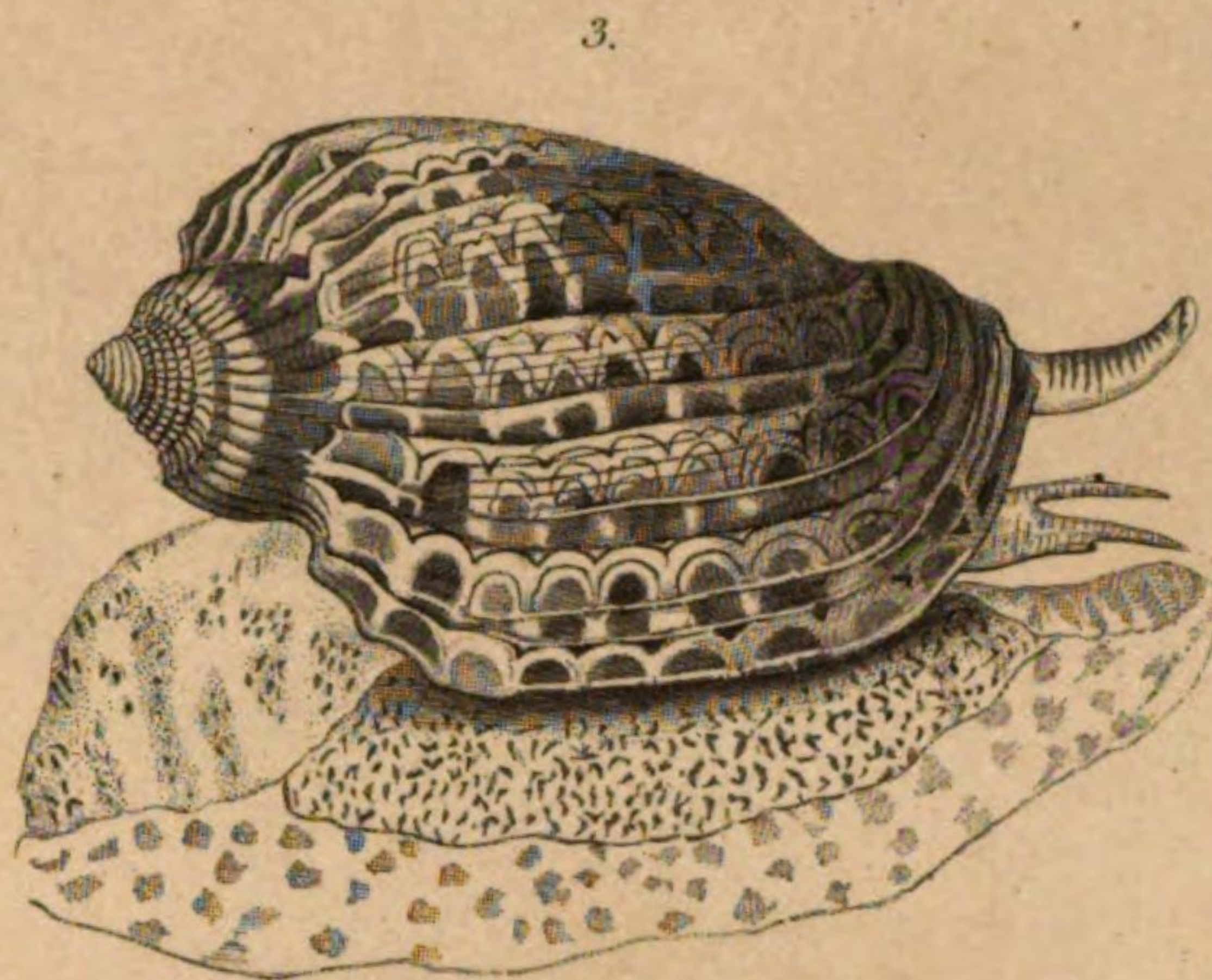
10.



Buccinum laevissimum.



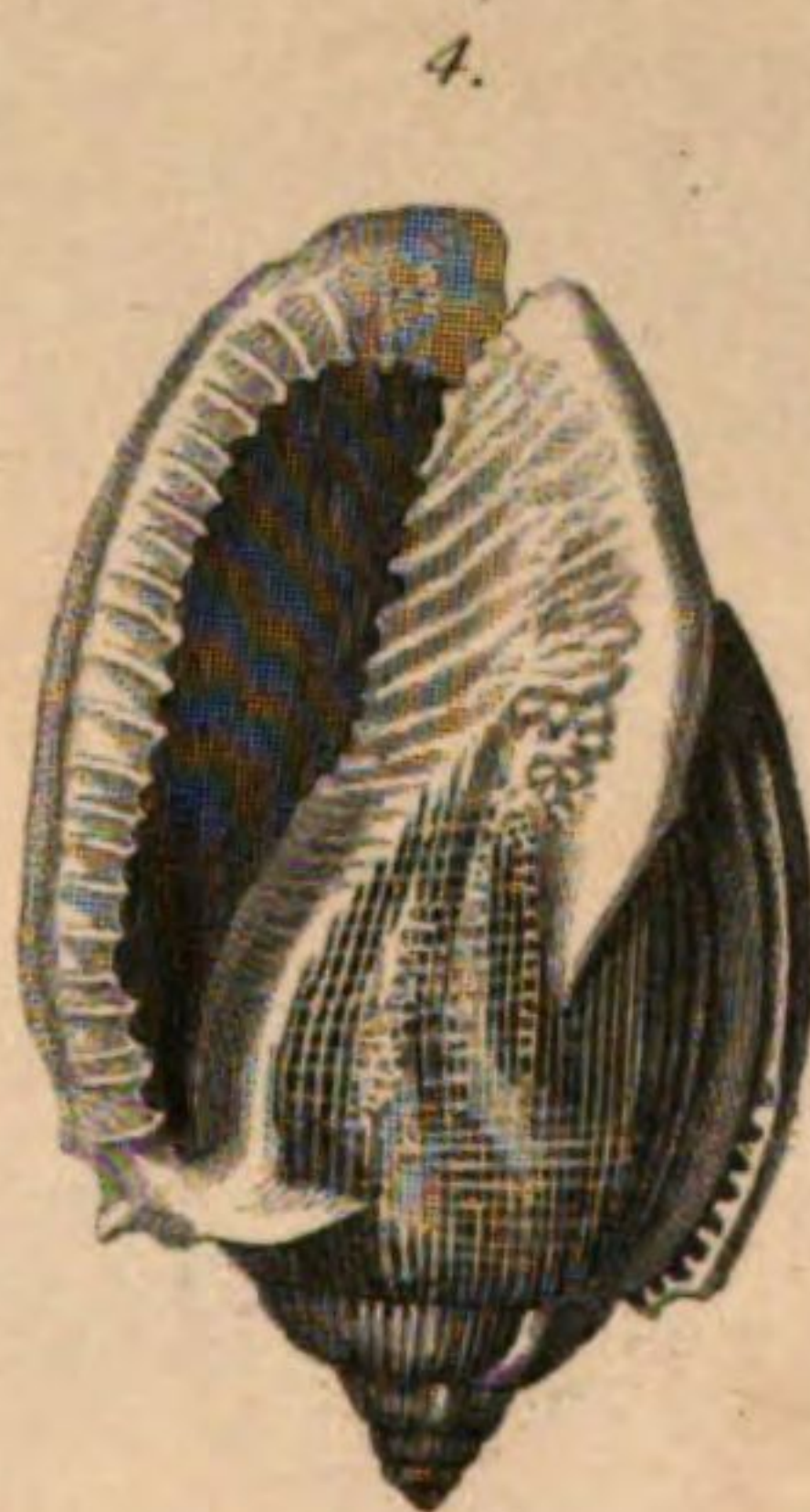
Voluta Japonica.



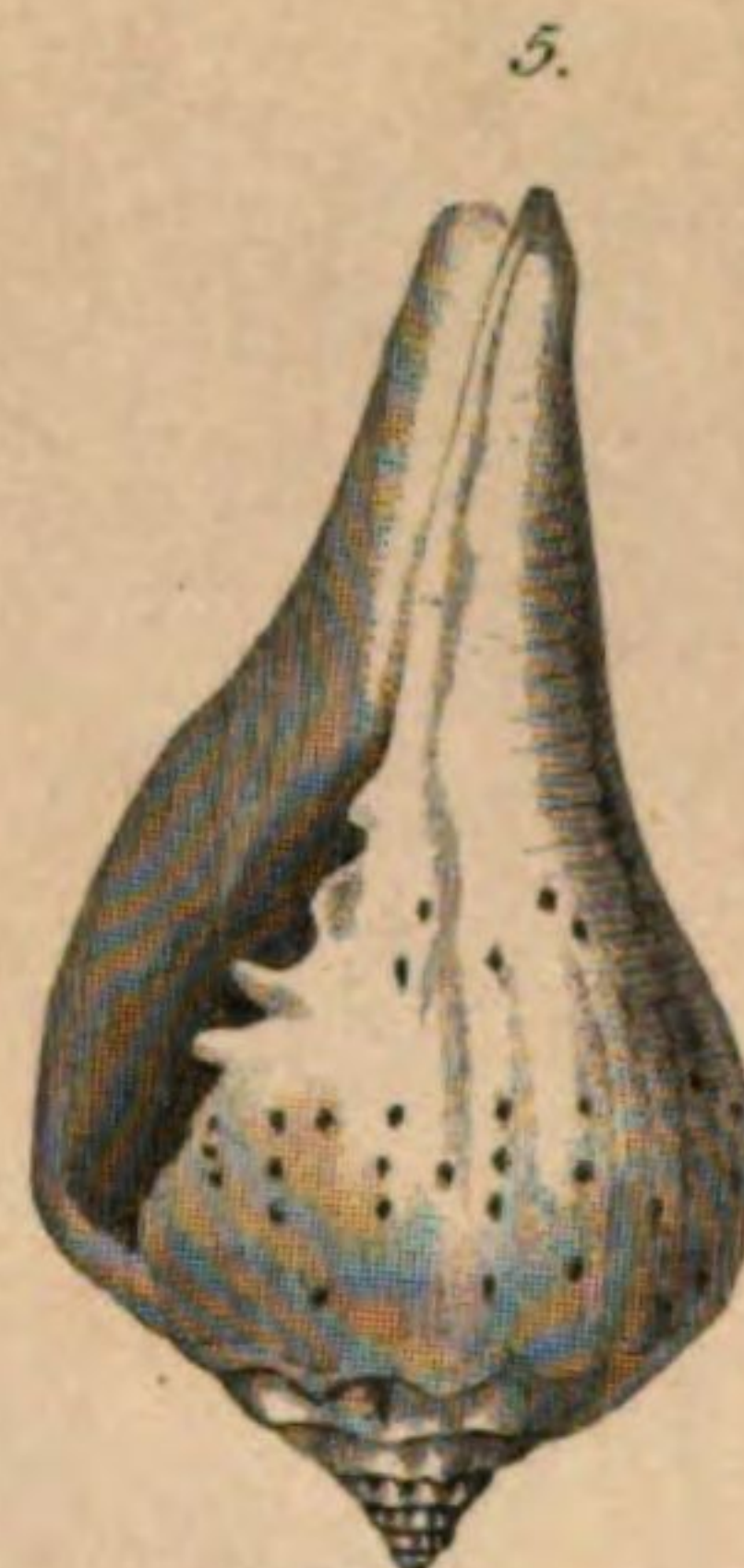
Harpa ventricosa.



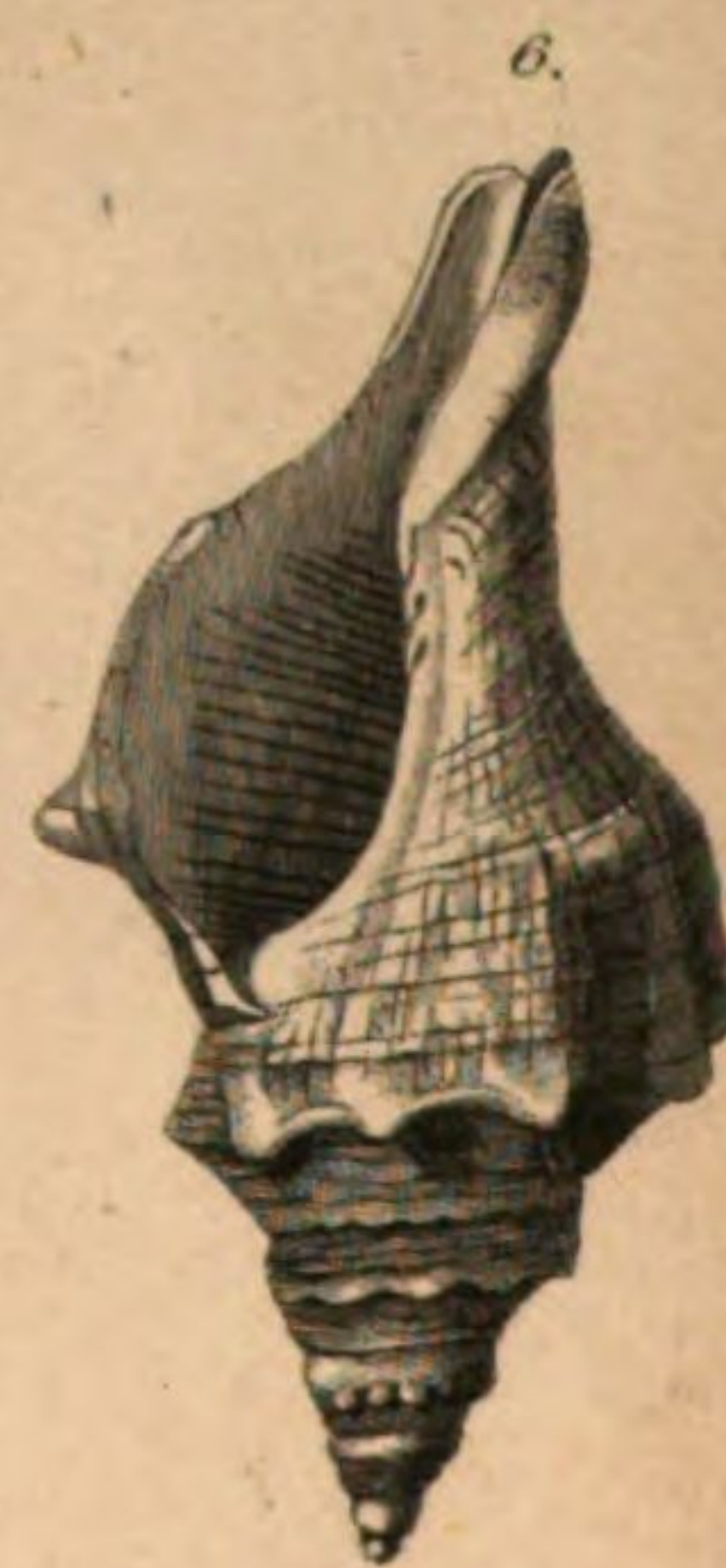
Terebra crenulata.



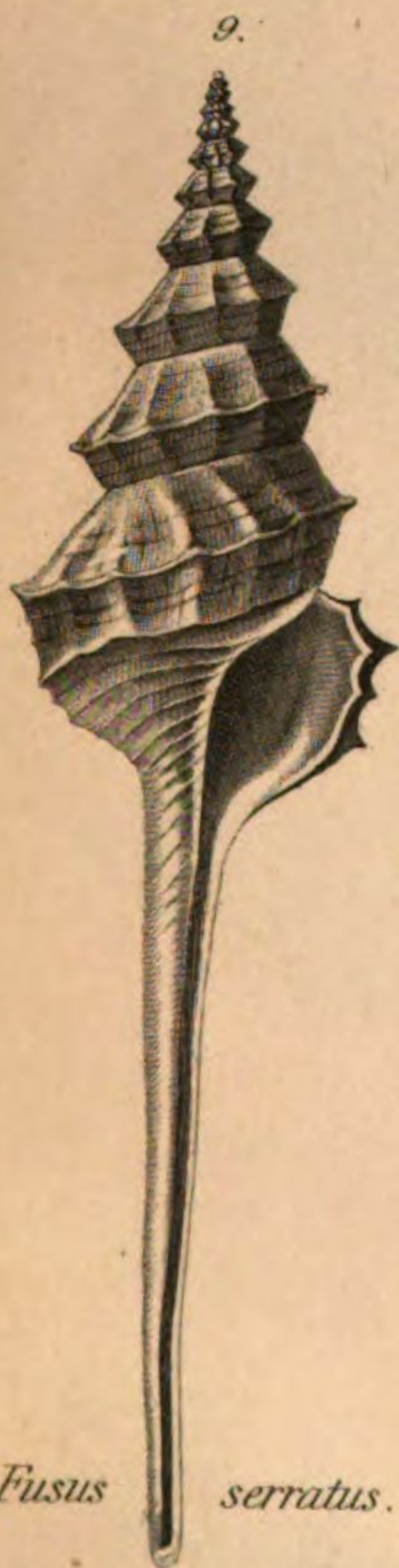
Cassis decussata.



Turbinella pyrum.



Fasciolaria trapezium.



Fusus serratus.



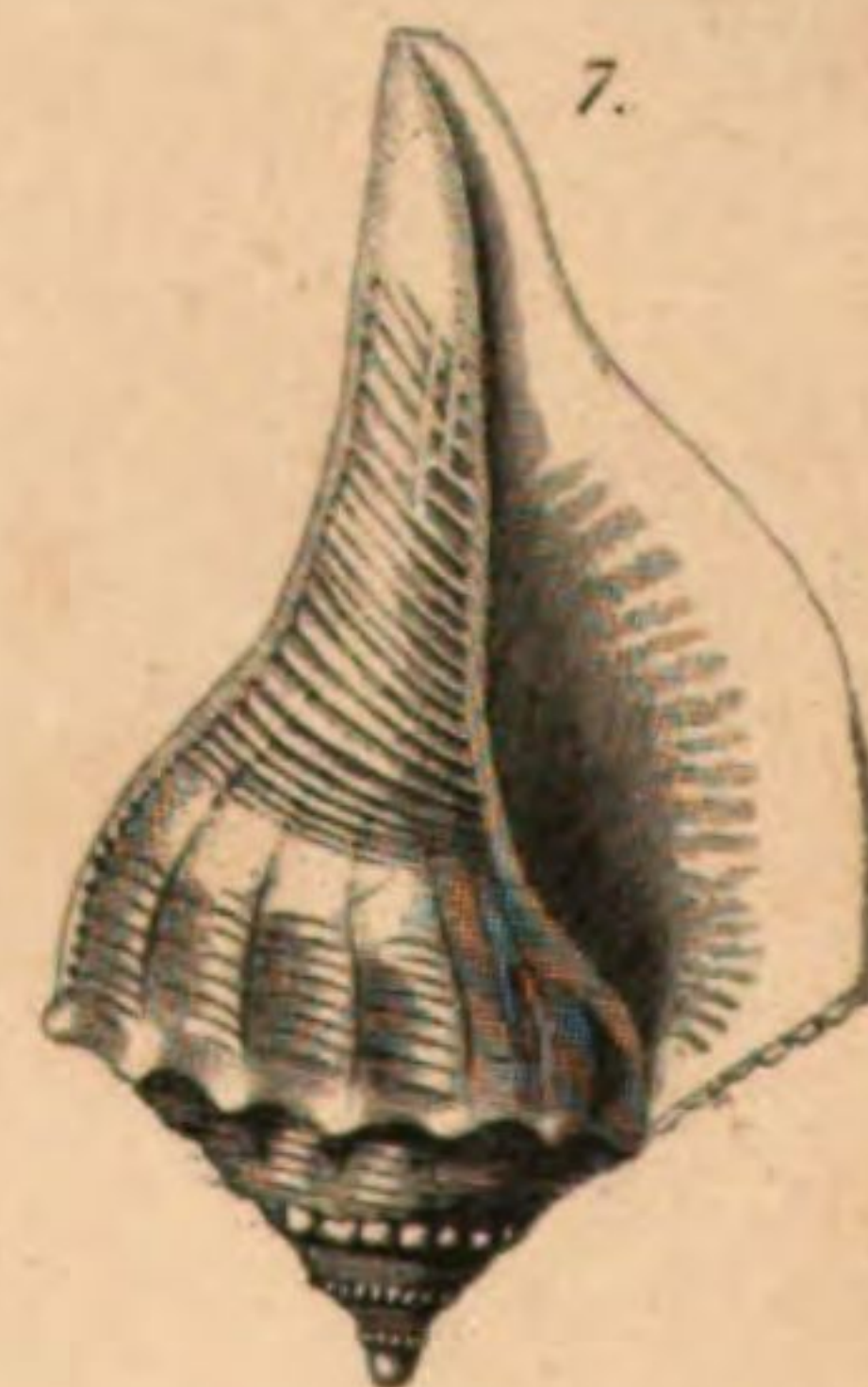
Fusus retroversus.



Murex haustellum.



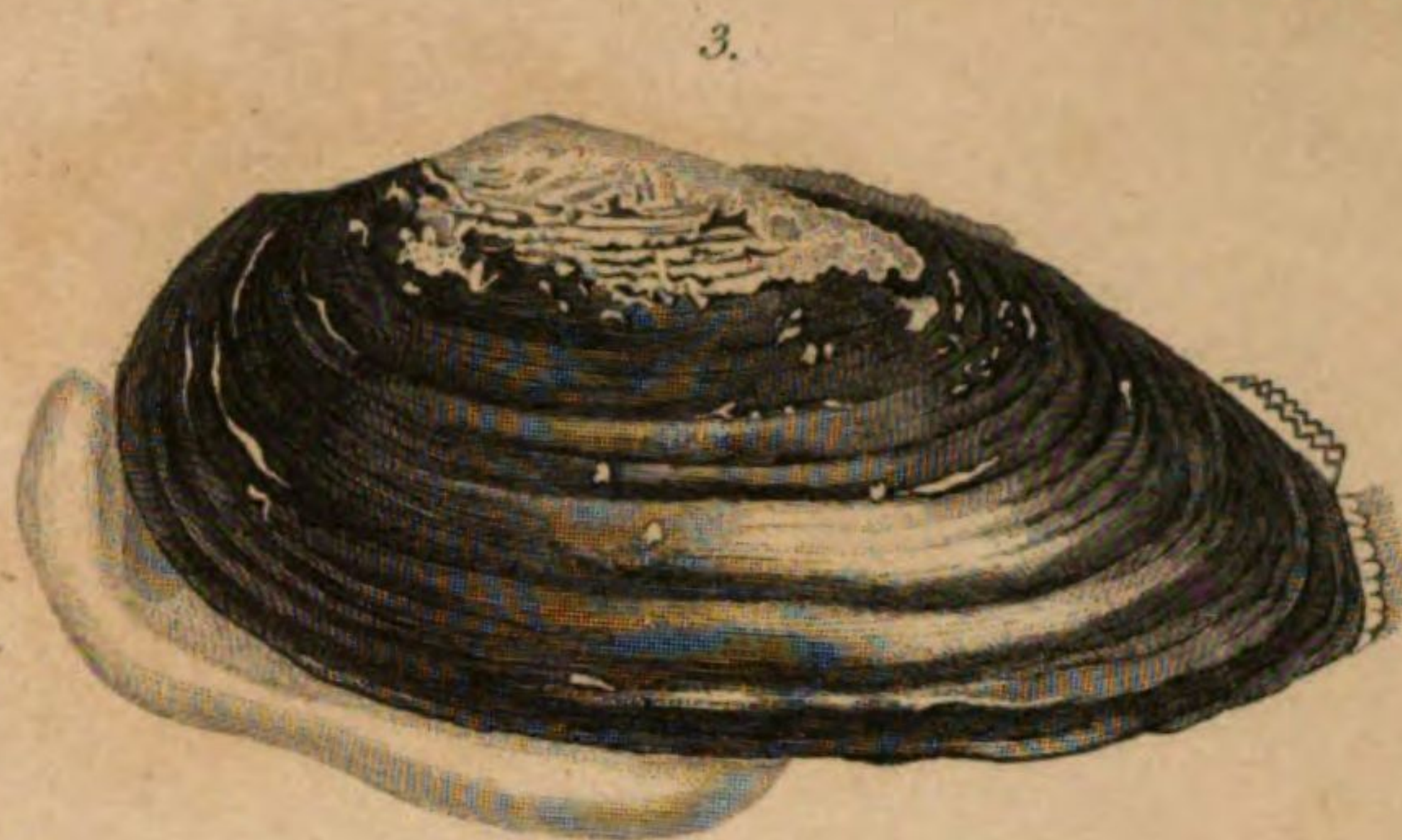
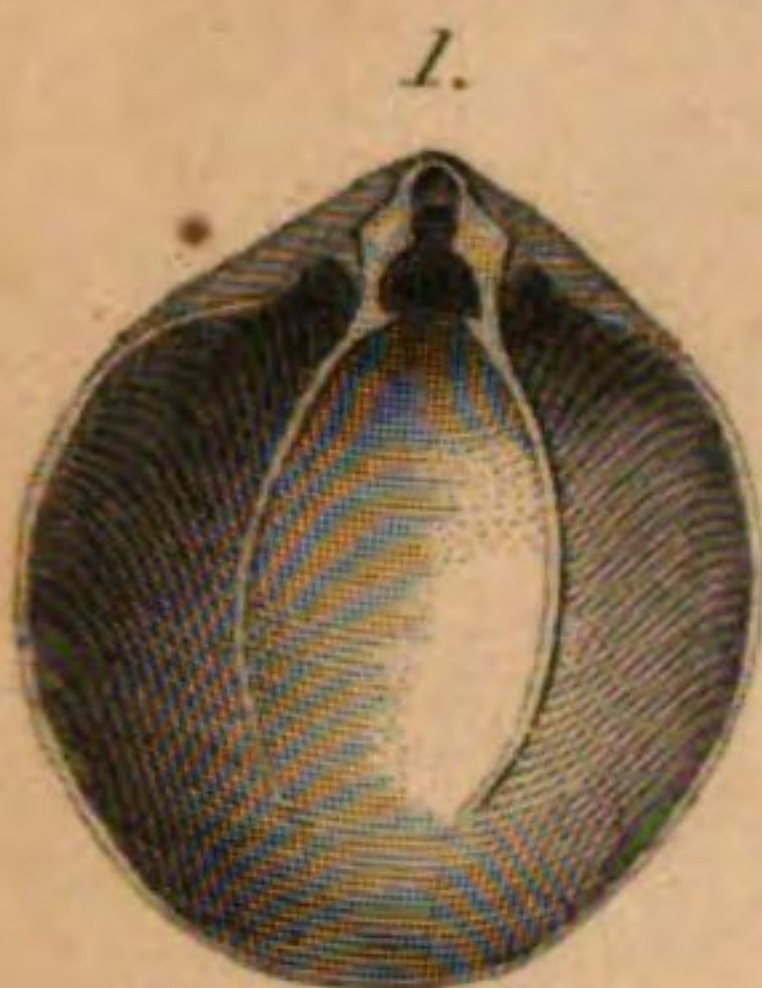
Scissurella crispata.



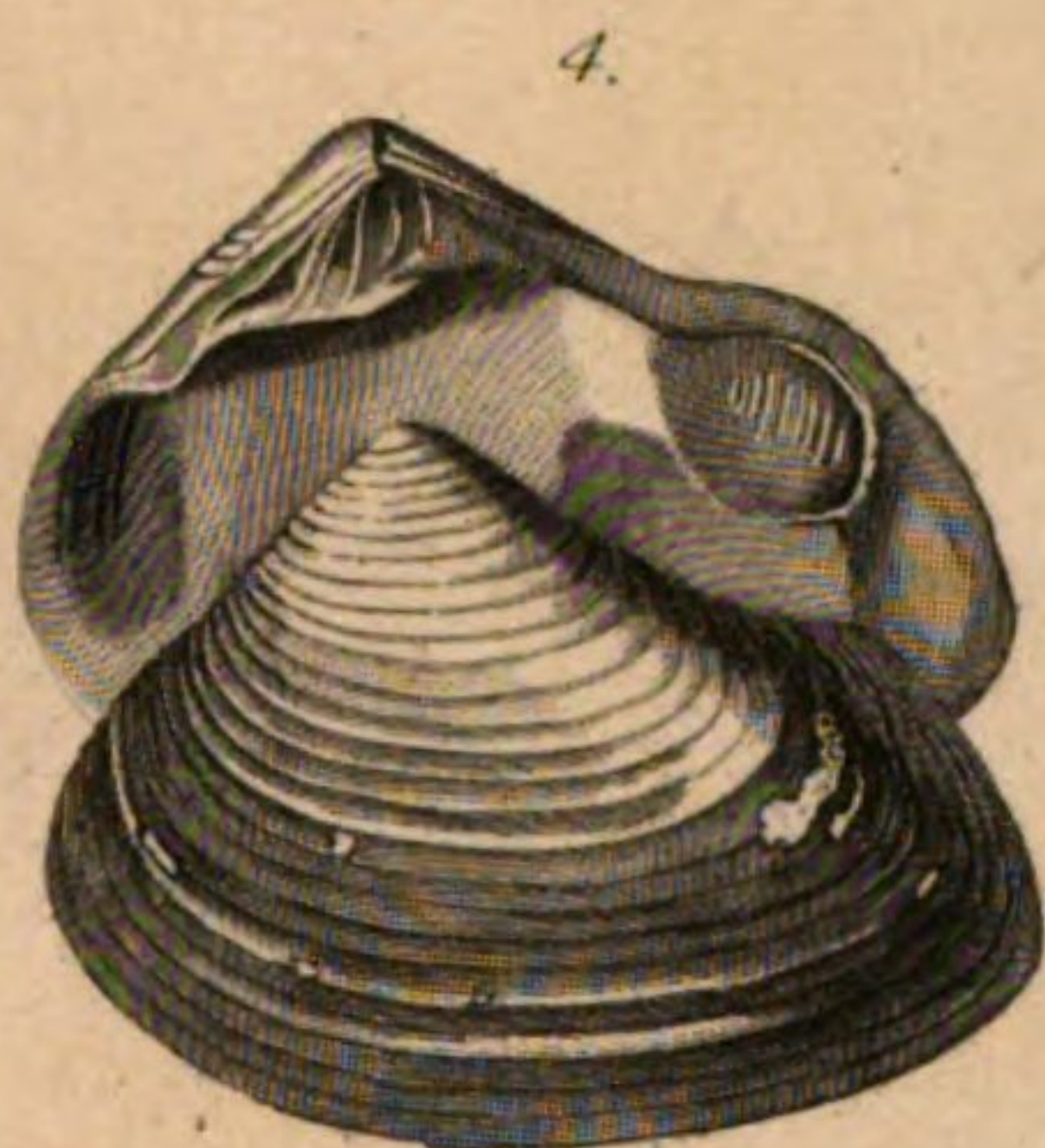
Pyrula perversa.



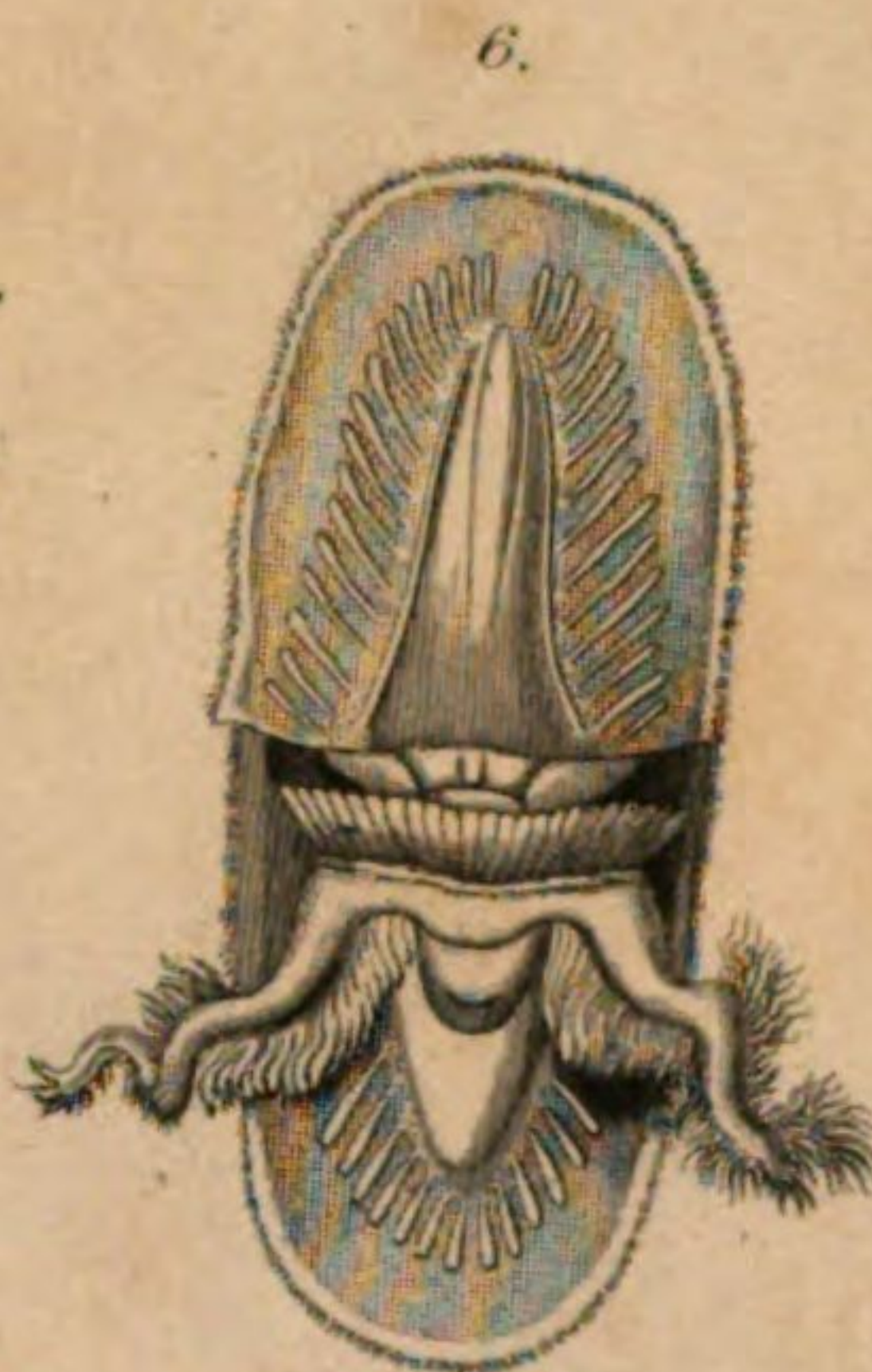
Terebratula cranium.



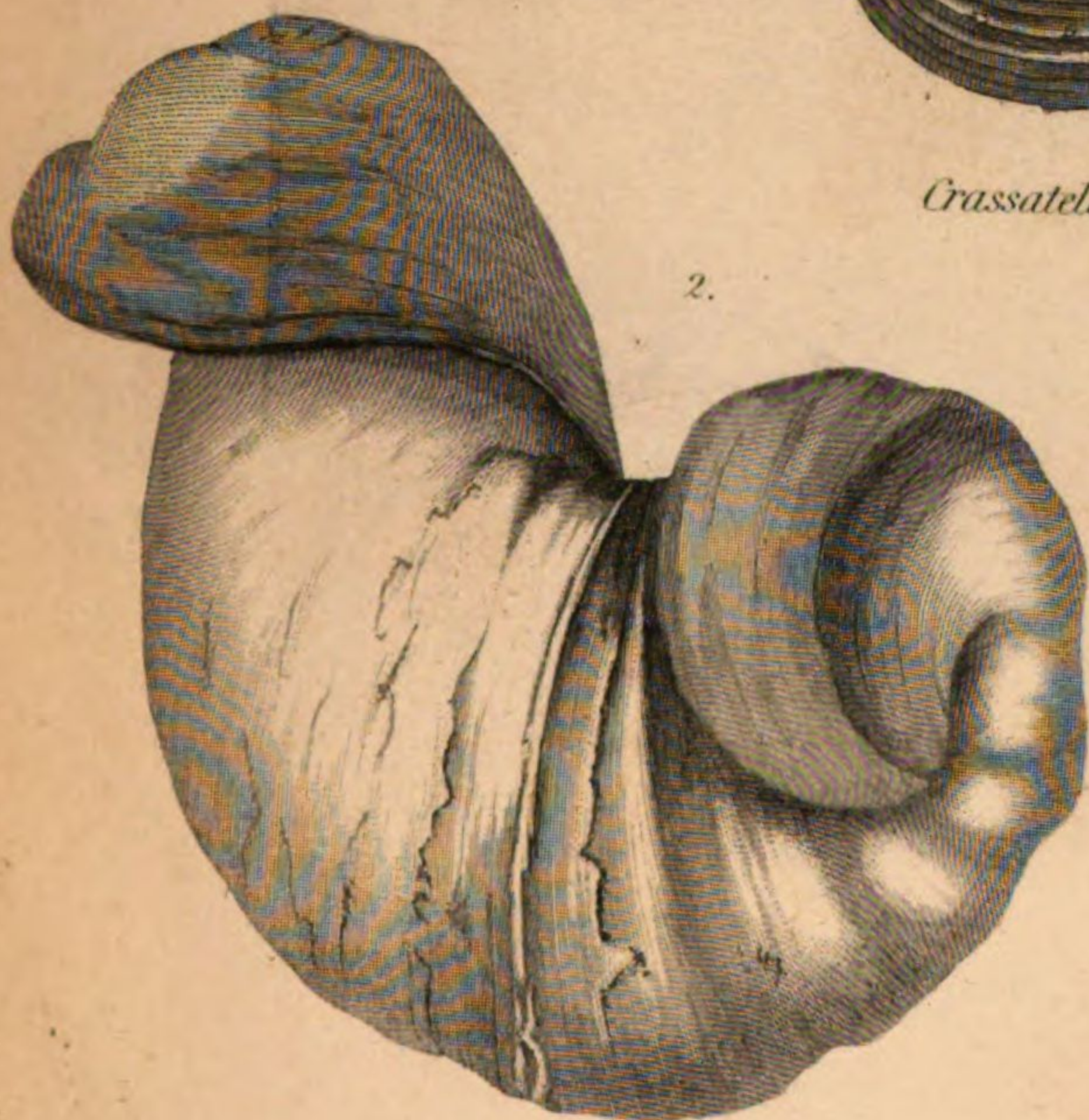
Unio Pictorum.



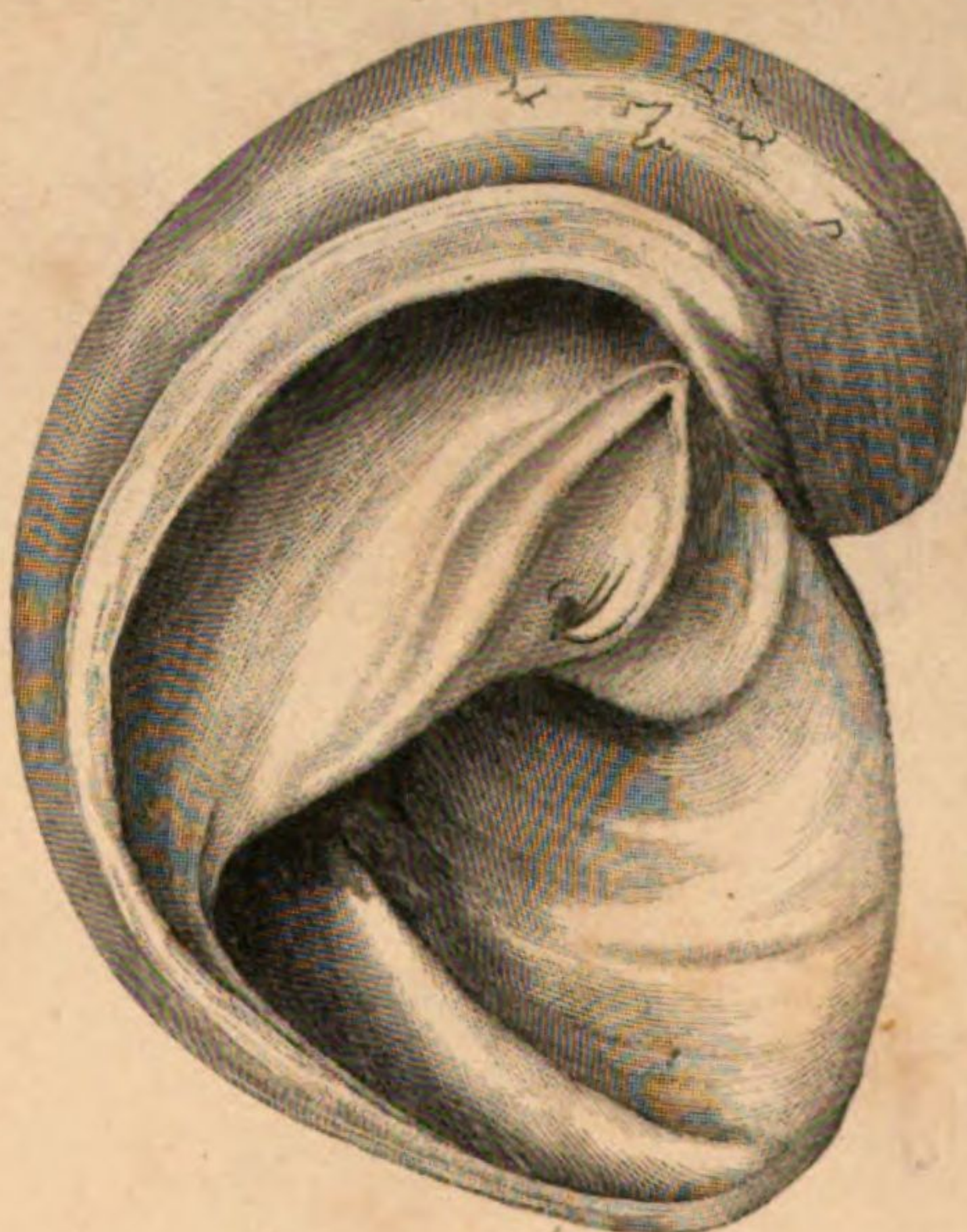
Crassatella sulcata.



Lingula anatina.



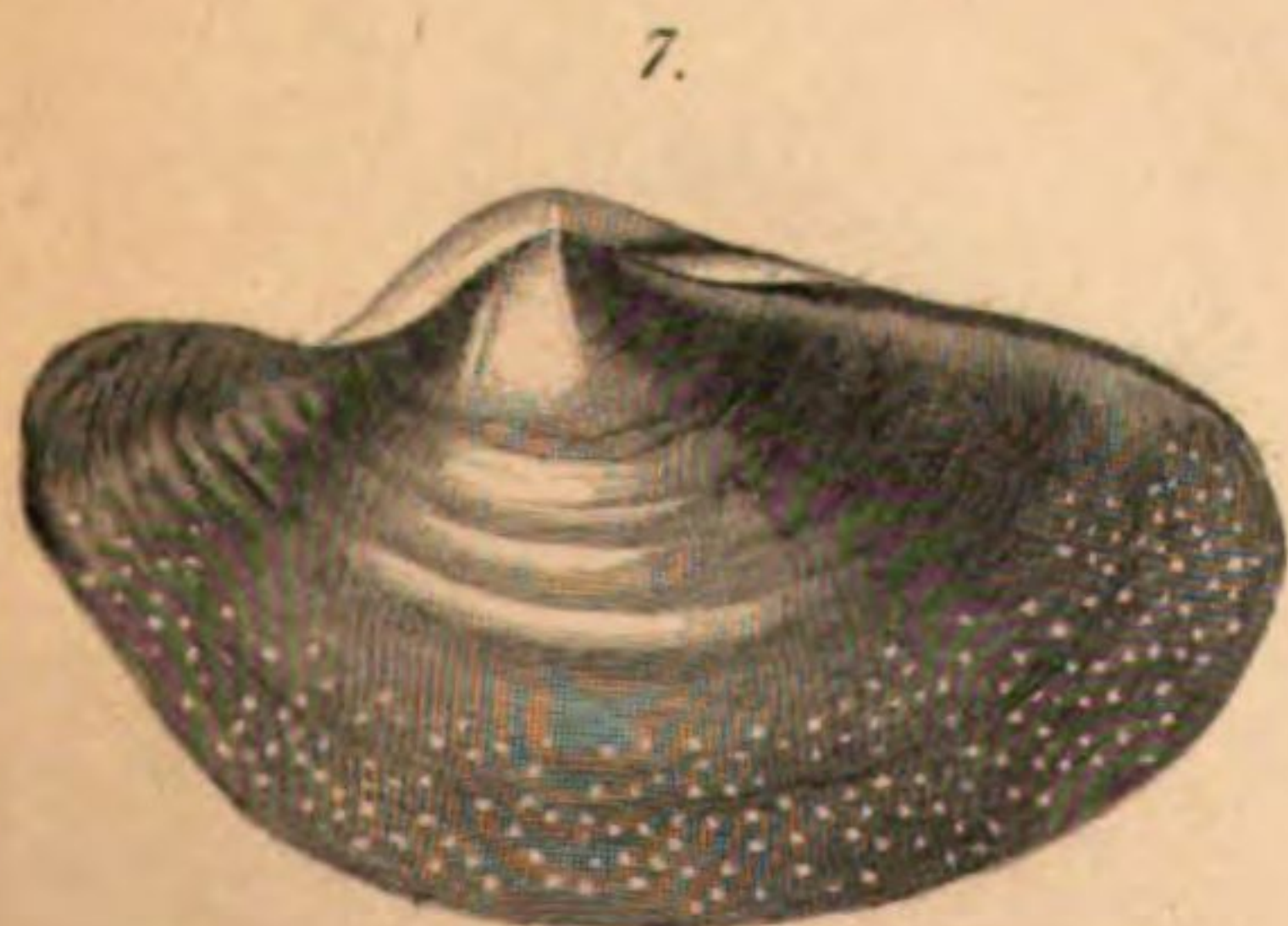
Diceras arietina.



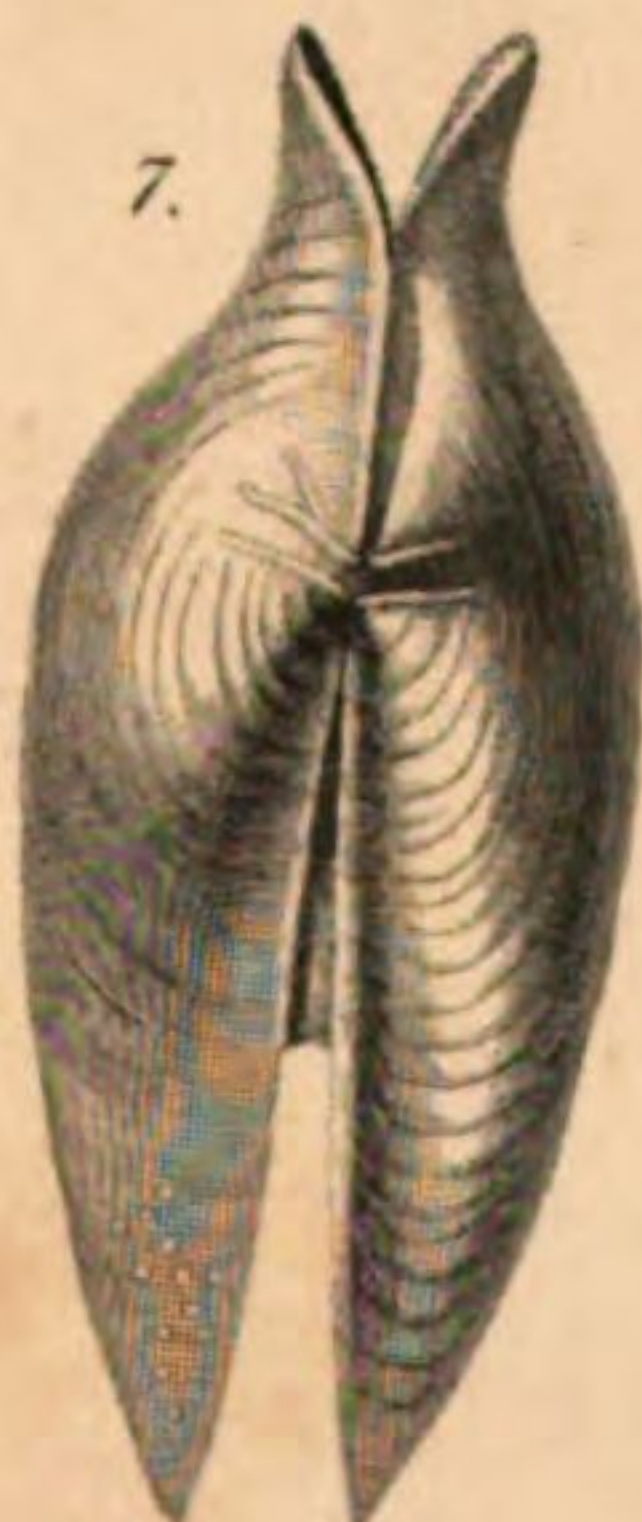
Diceras arietina.



Lingula anatina.



Anatina hispidula.



Cydas cornea.



Teredo navalis.

1.



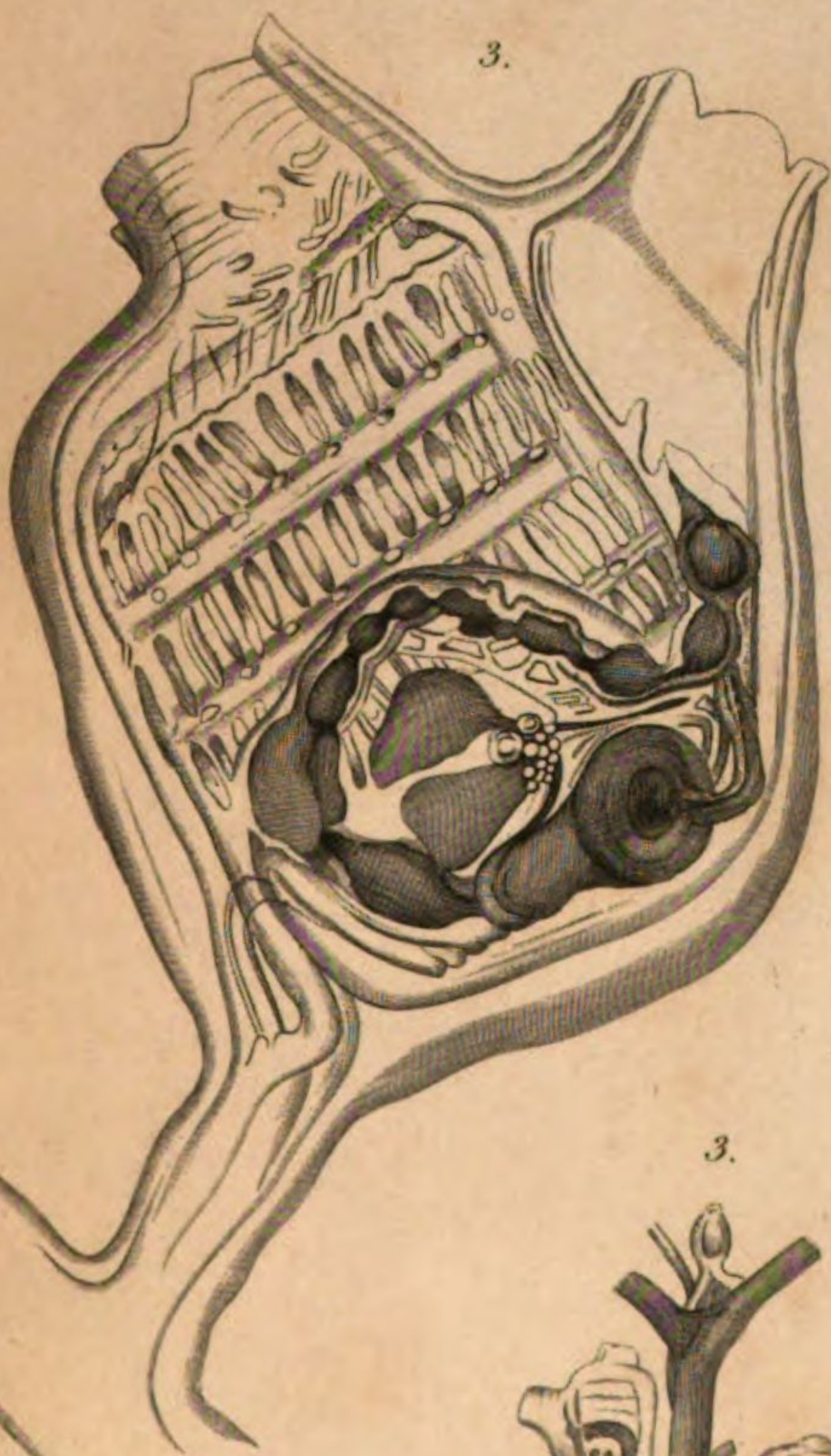
Clavellina lepadiformis.

2.



Ciona intestinalis.

3.



Ascidia N. S. Lister.

3.



4.



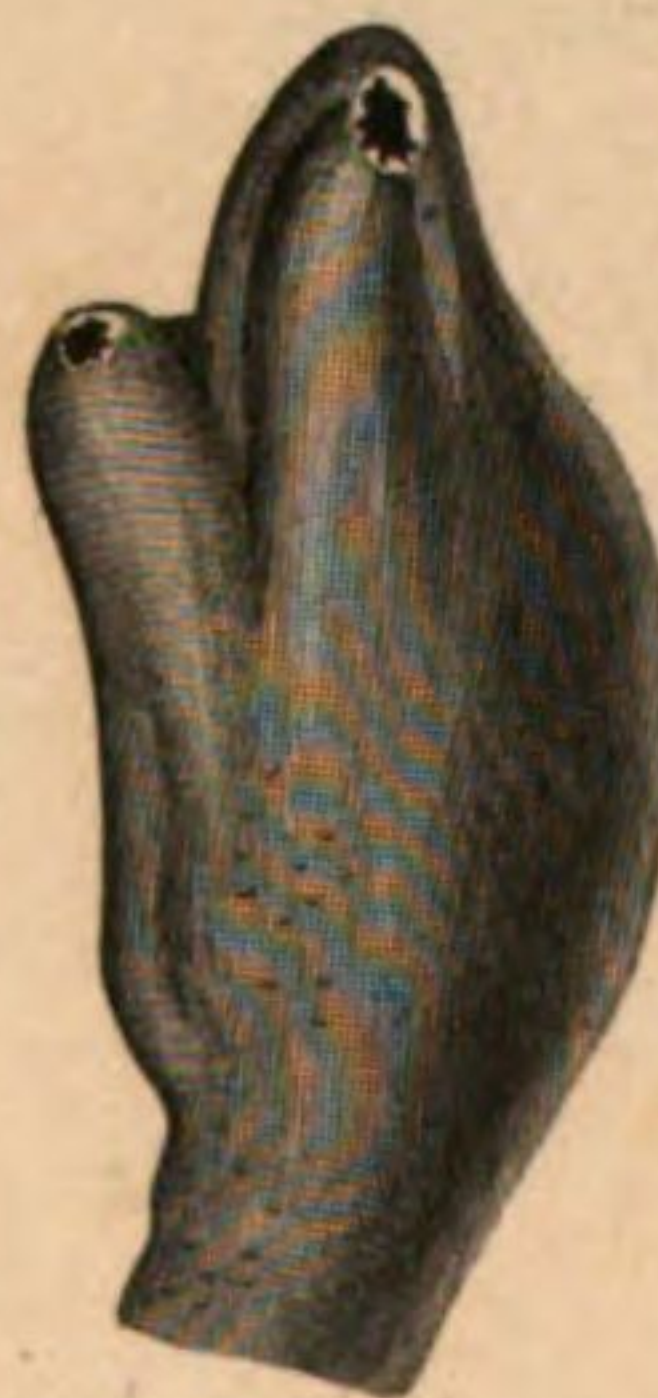
Botryllus polycyclus.

5.



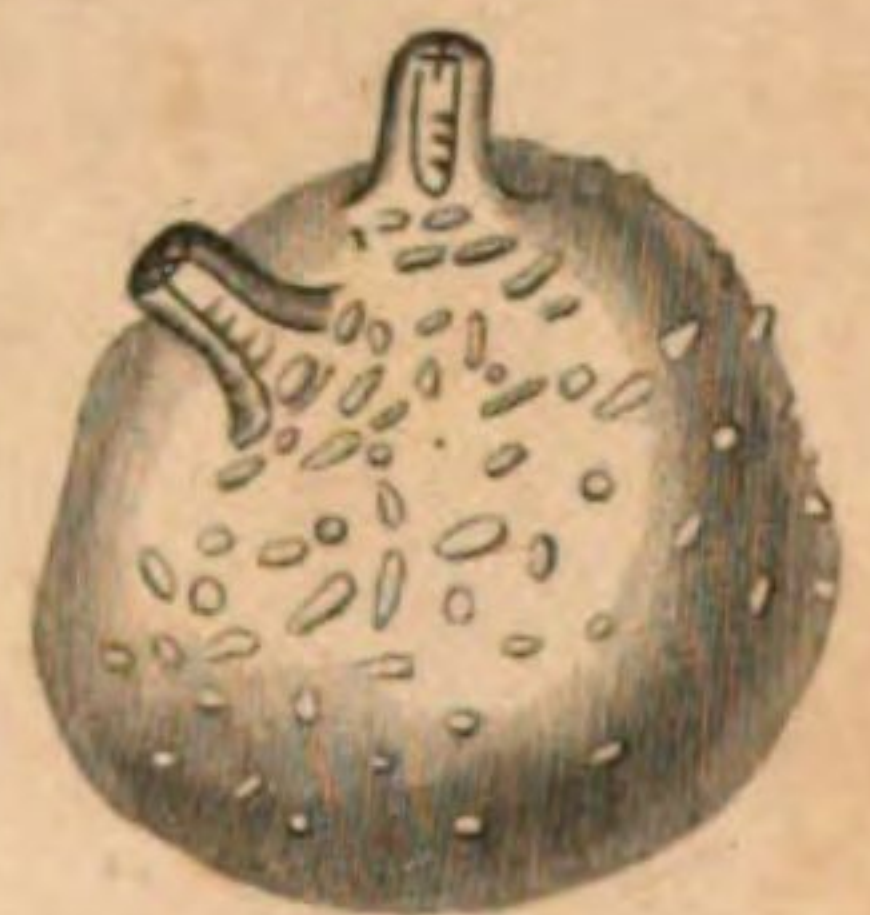
Boltenia ovifera.

7.



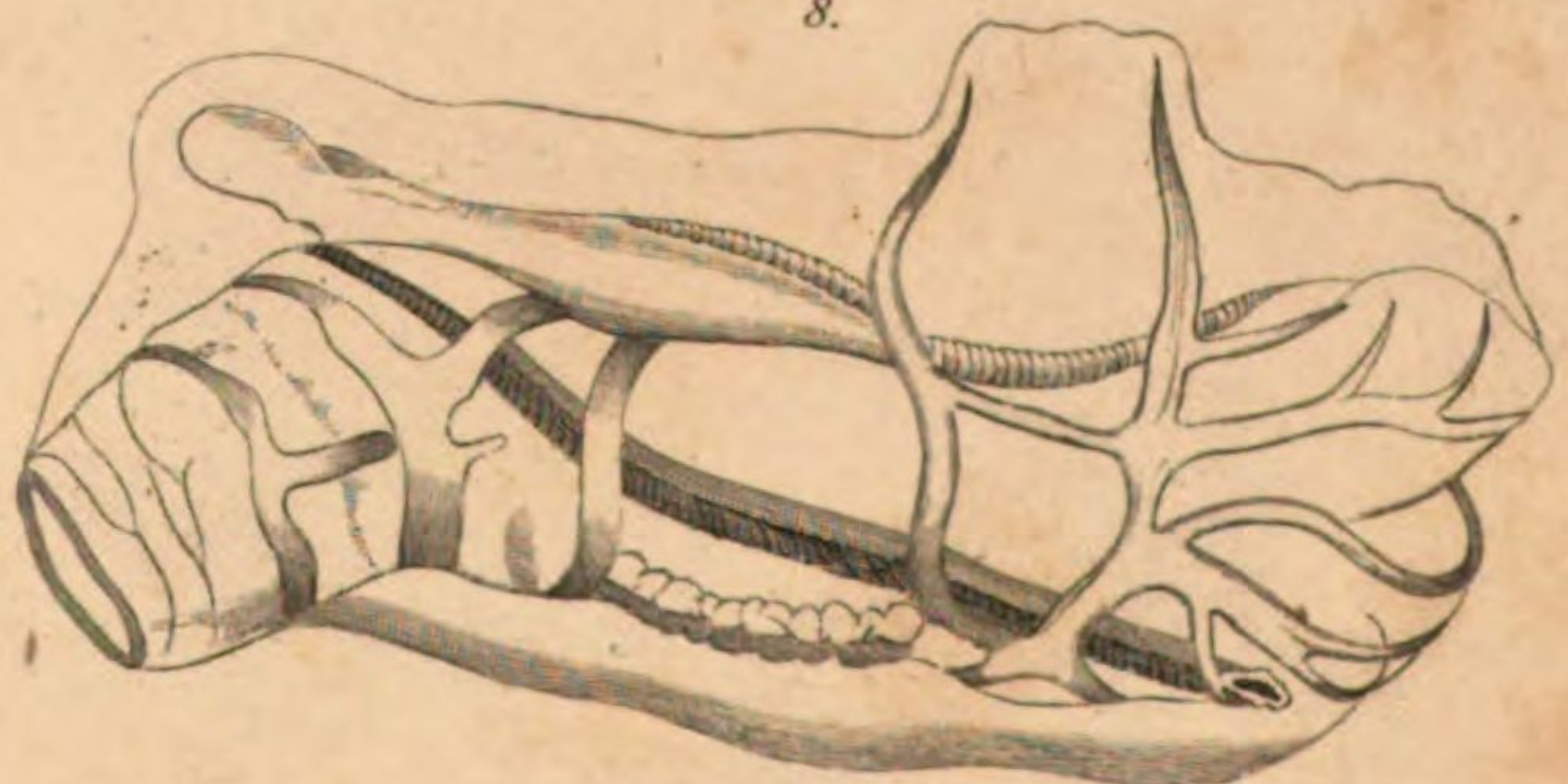
Phallusia nigra.

6.



Cynthia momus.

8.



Salpa cristata.



Drawn with Camera Lucida, by Thos. Allan, Esq. F.R.S.E.

Eng'd by G. Gibson, Edin.

FINGAL'S CAVE, STAFFA.



Drawn with Camera Lucida by Thos. Allan, Esq. F.R.S.E.

Eng. by G. Gibson, Edin.

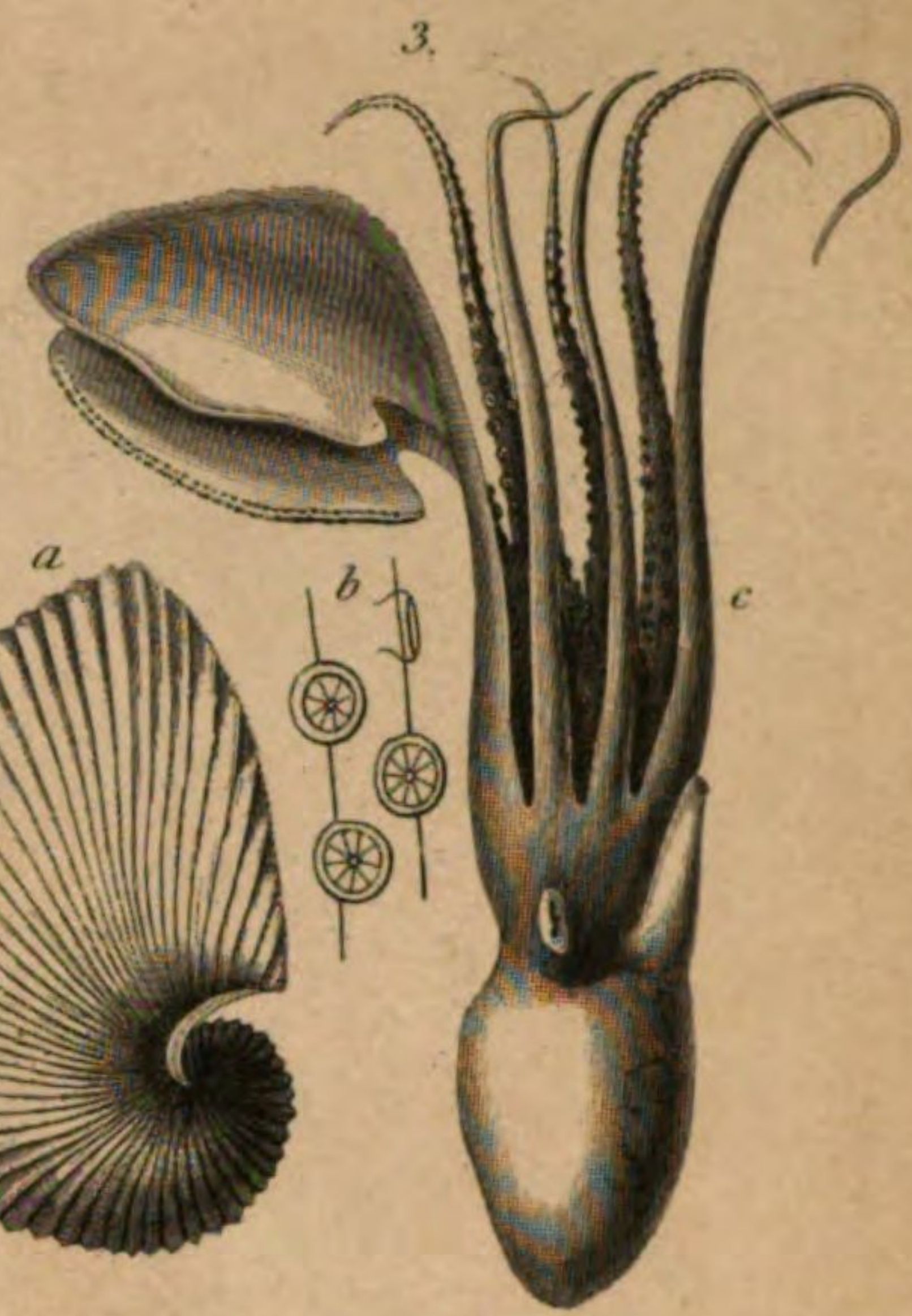
FINGAL'S CAVE, STAFFA.



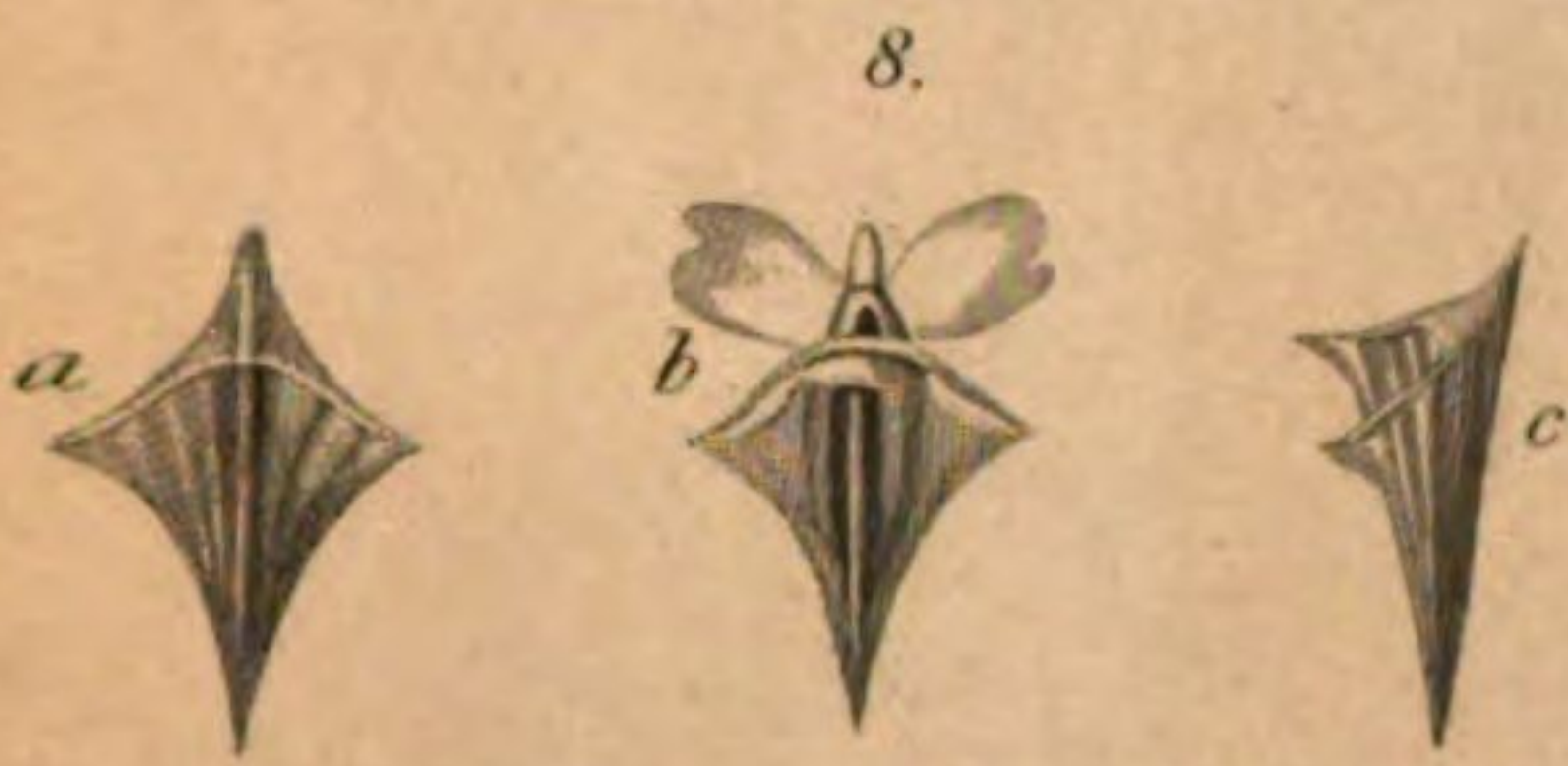
Spirula australis.



Octopus cirrhosus.



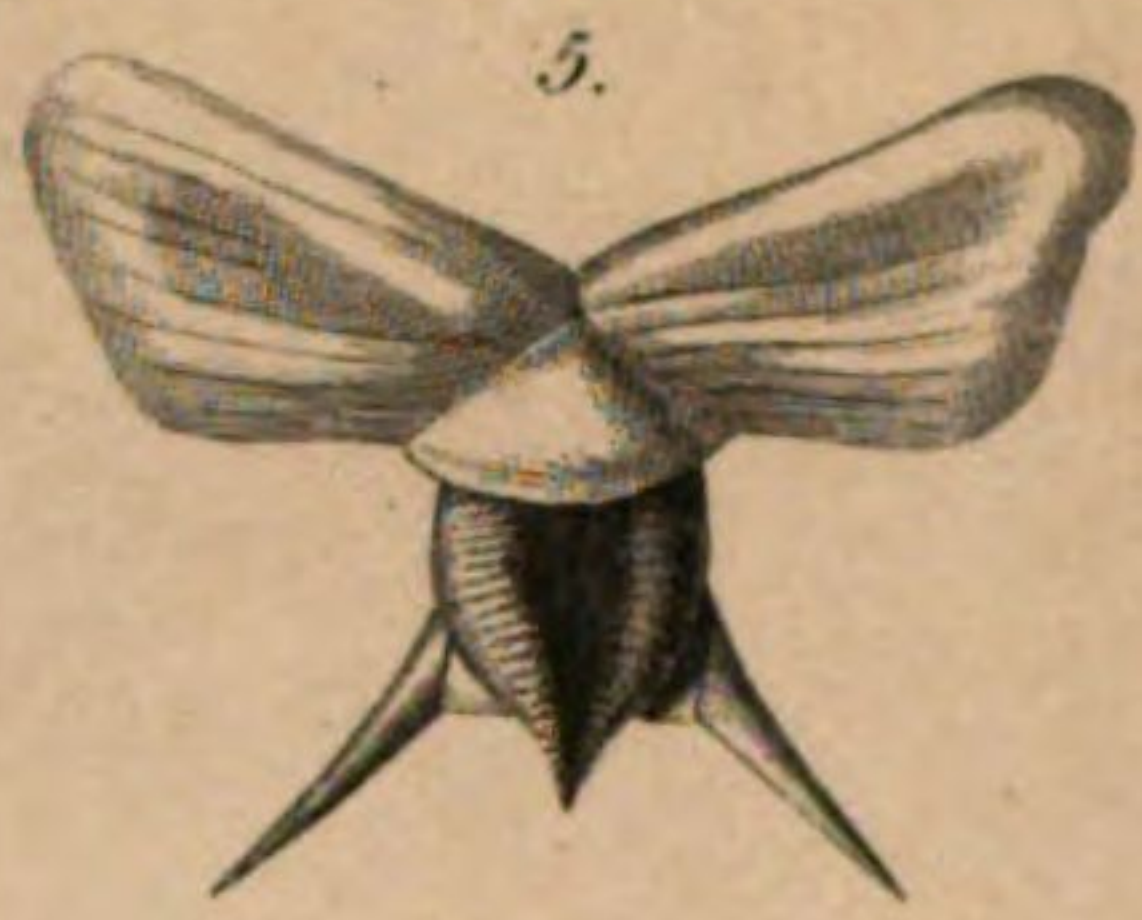
Argonauta Argo.



Cleodora lanceolata.



Nautilus umbilicatus.



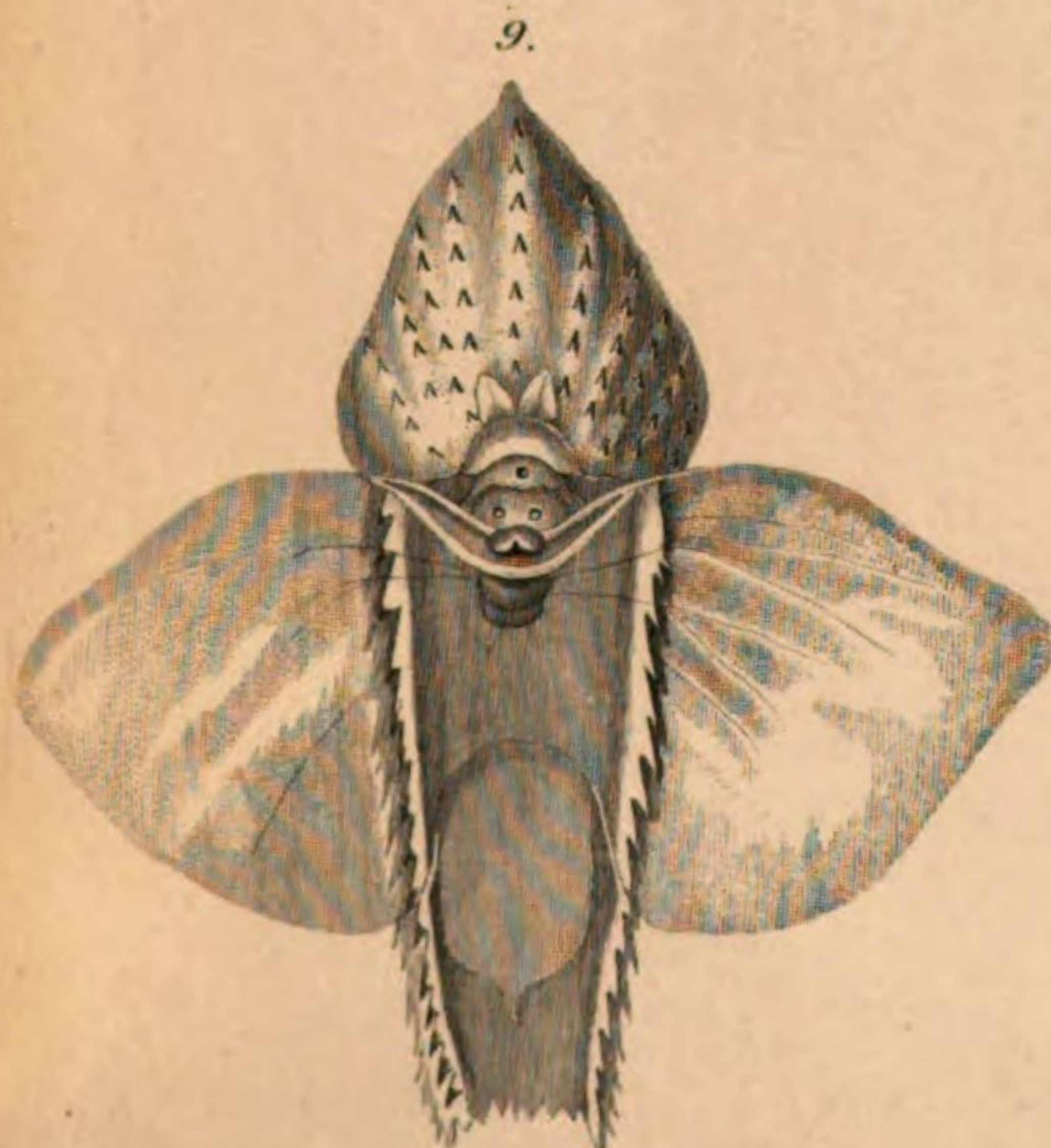
Hyalea globosa.



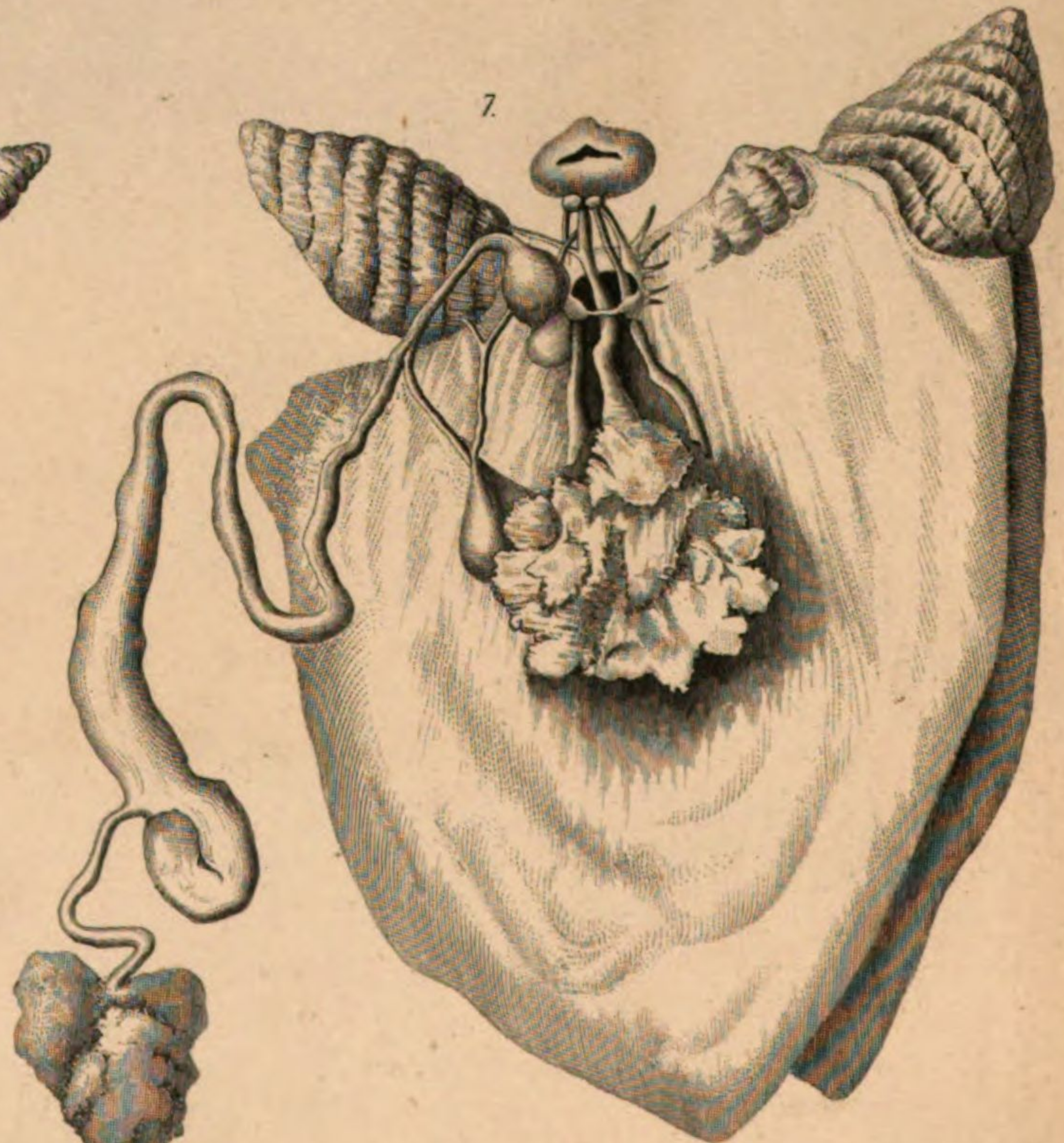
Pneumodermos diaphanus.



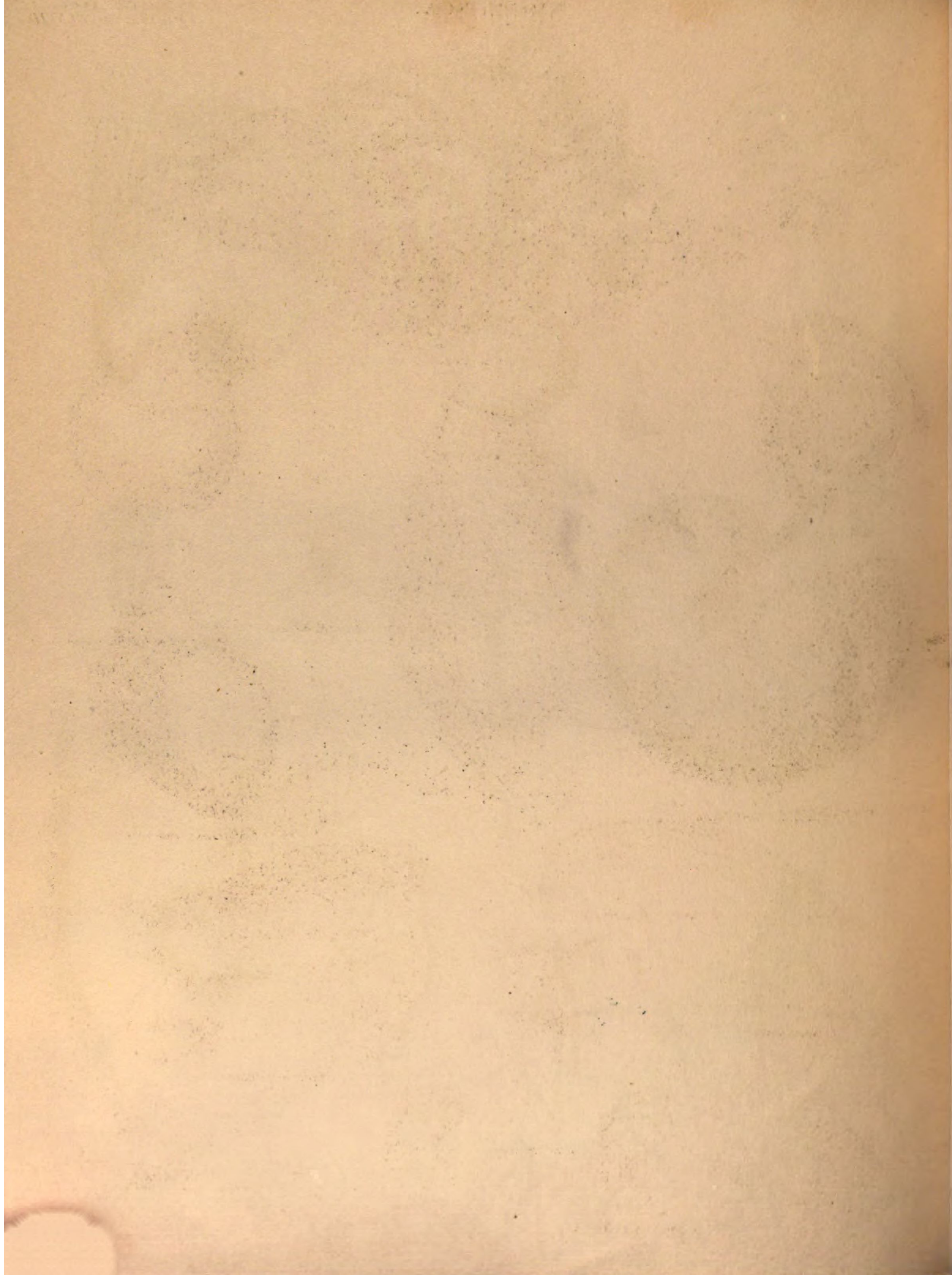
Clio borealis.

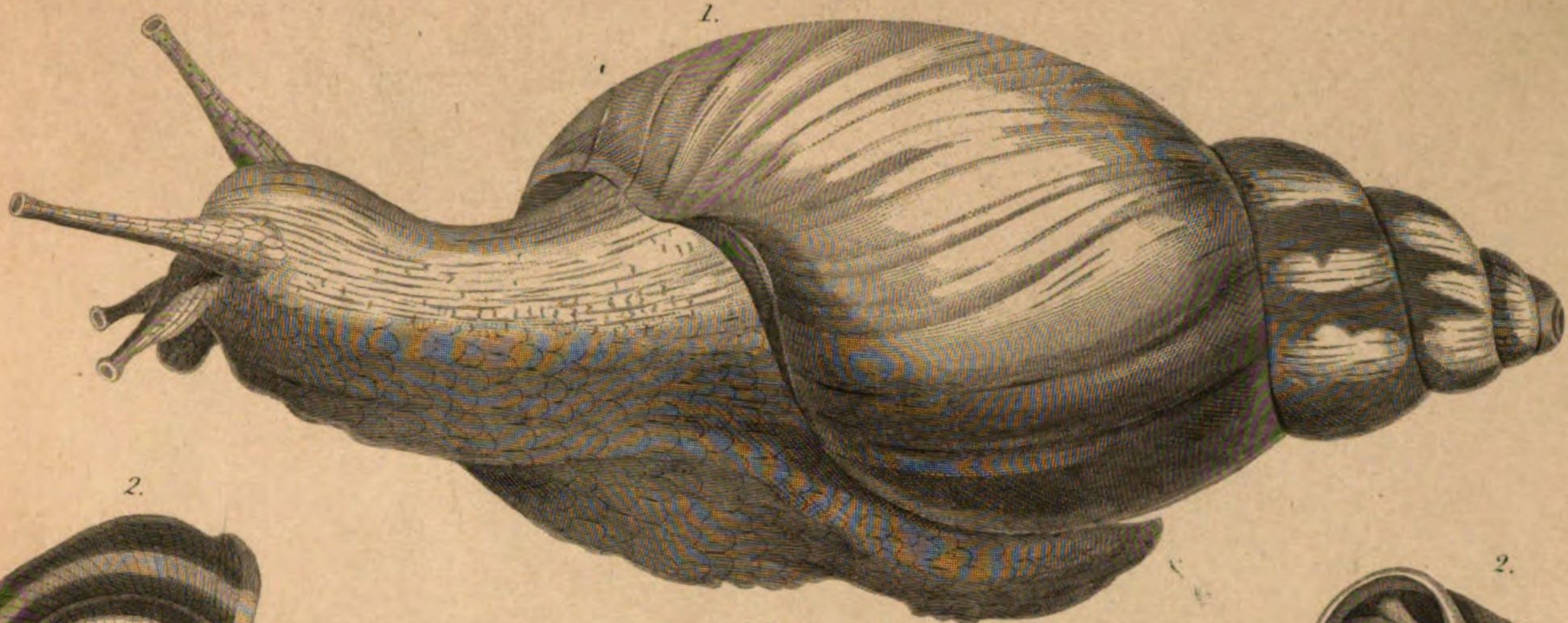


Cymbulia Peronii.



Clio borealis.





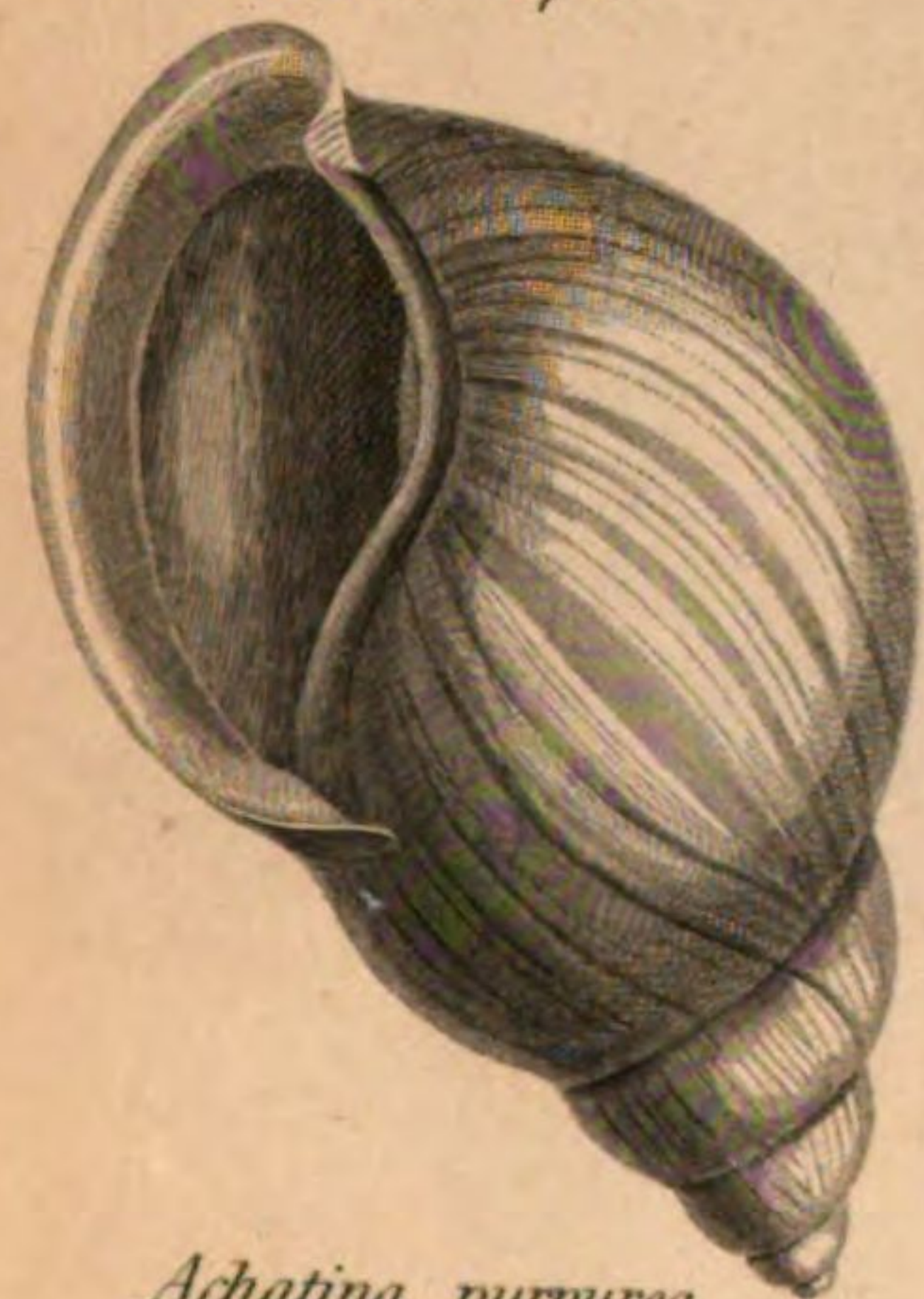
Achatina fasciata.



Helix cepa.



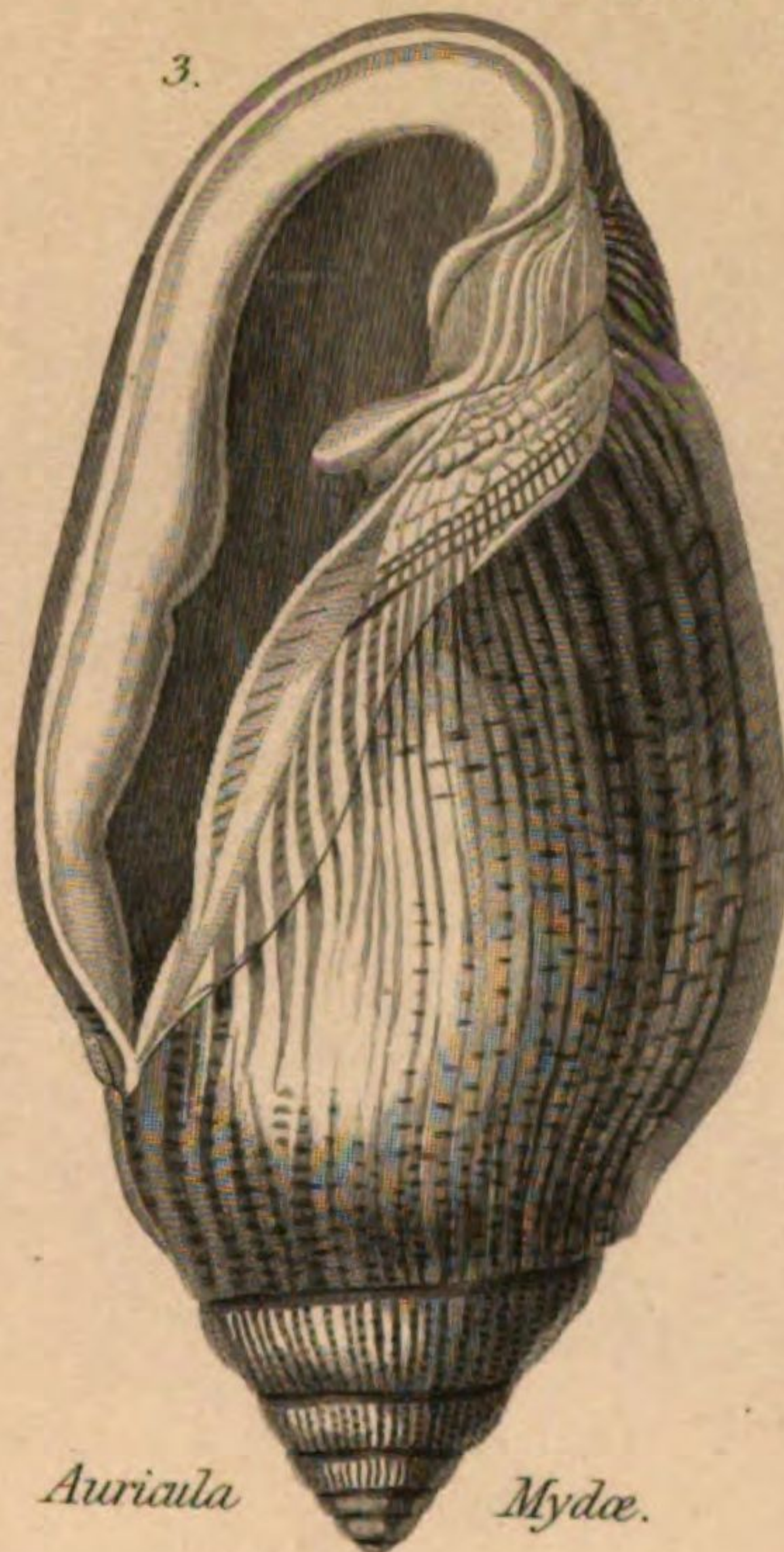
Helix cepa.



Achatina purpurea.



5.

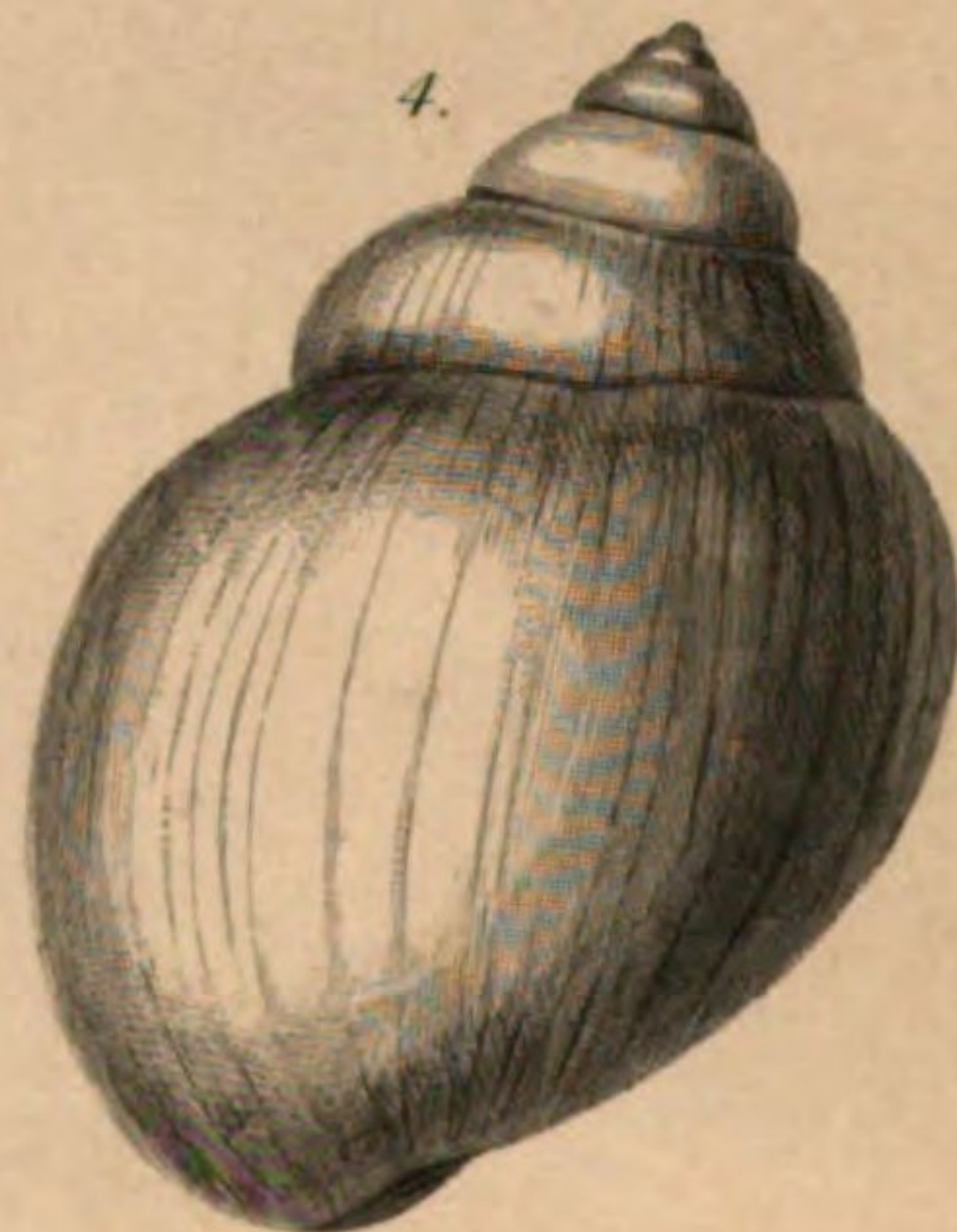


Auricula

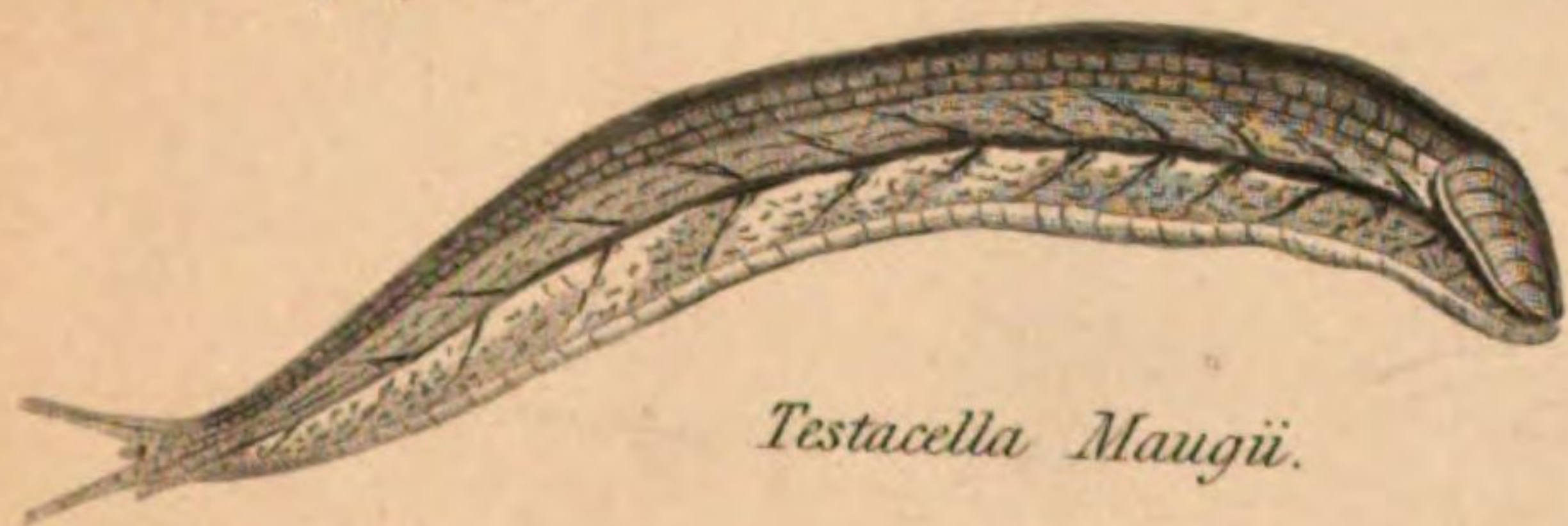
Mydæ.



6.



Ampullaria virescens.



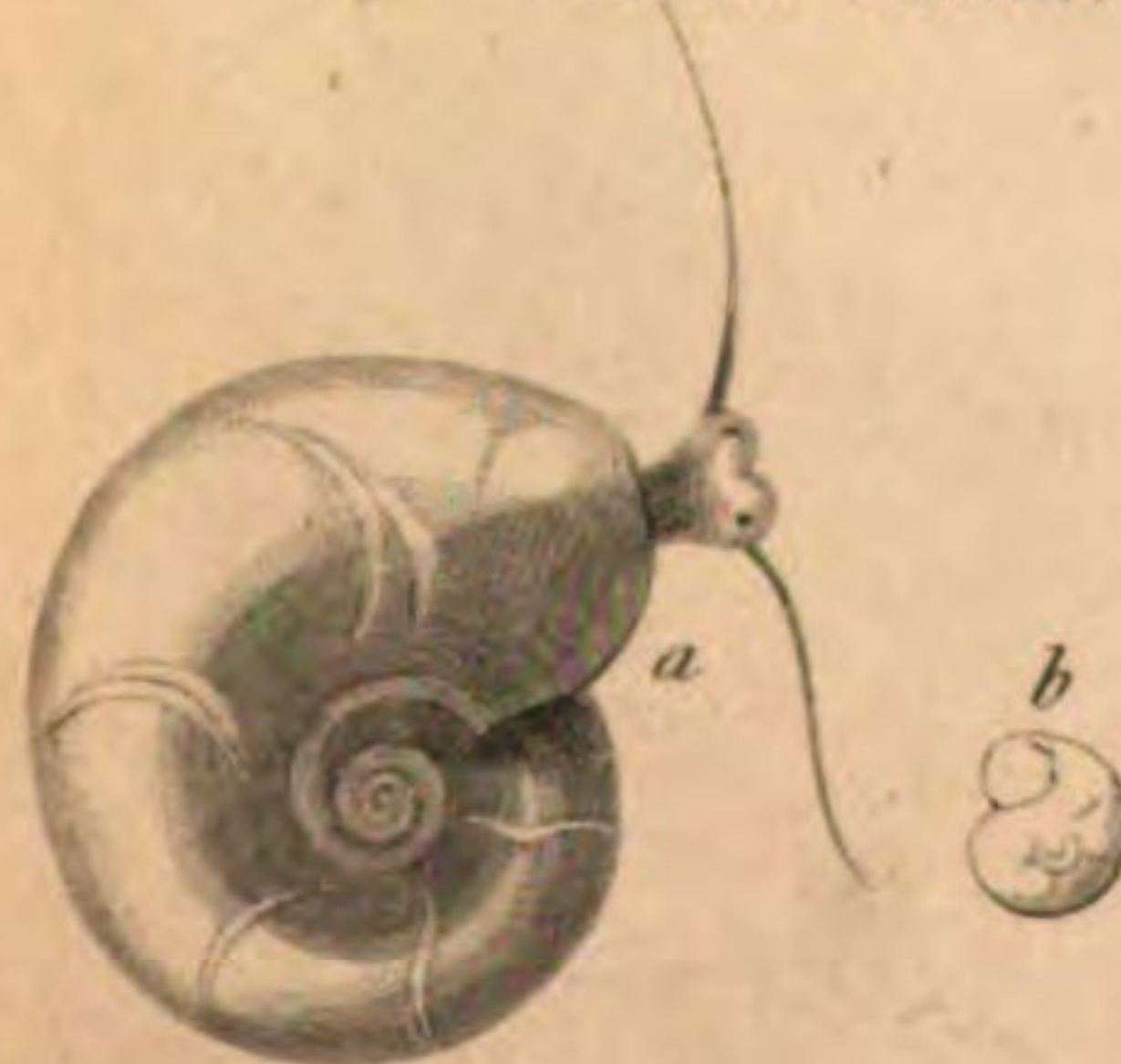
Testacella Maugii.



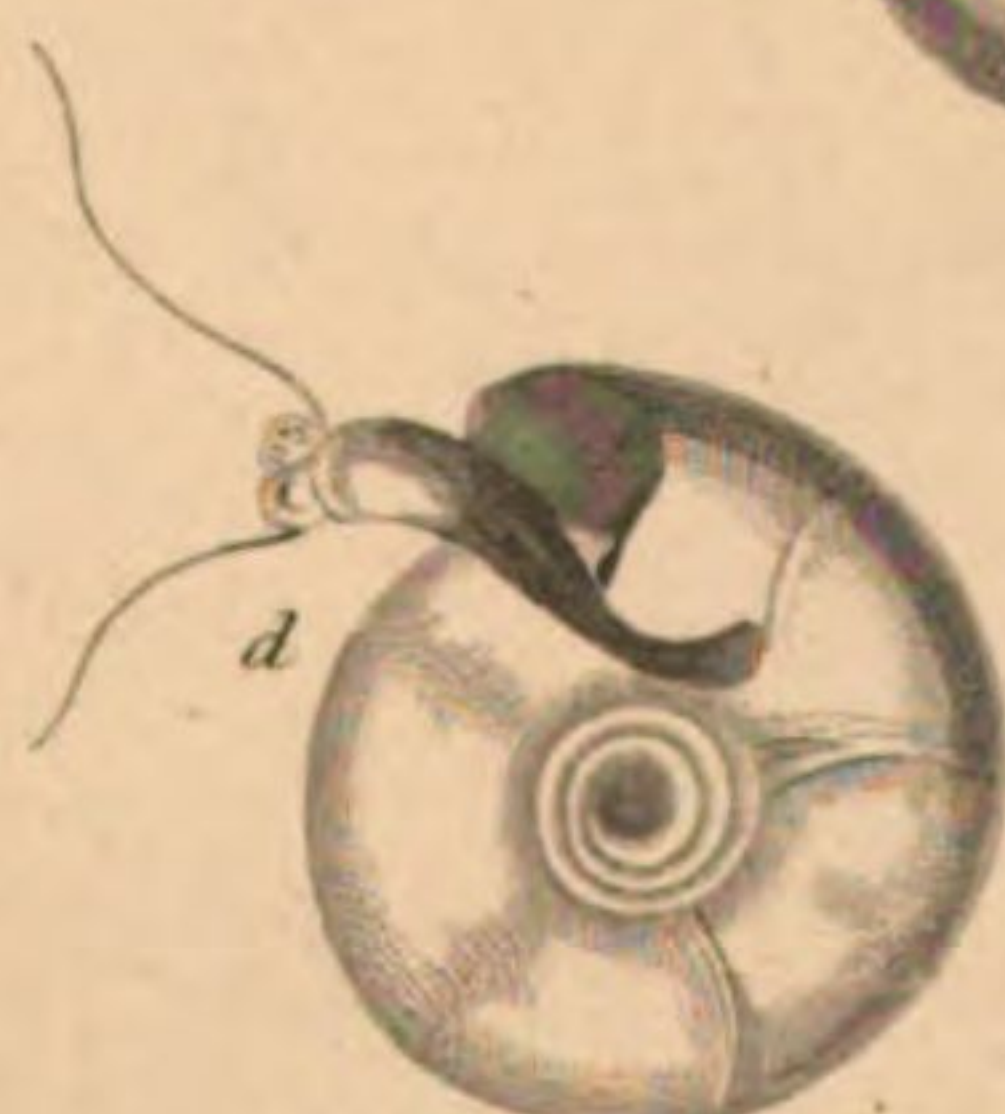
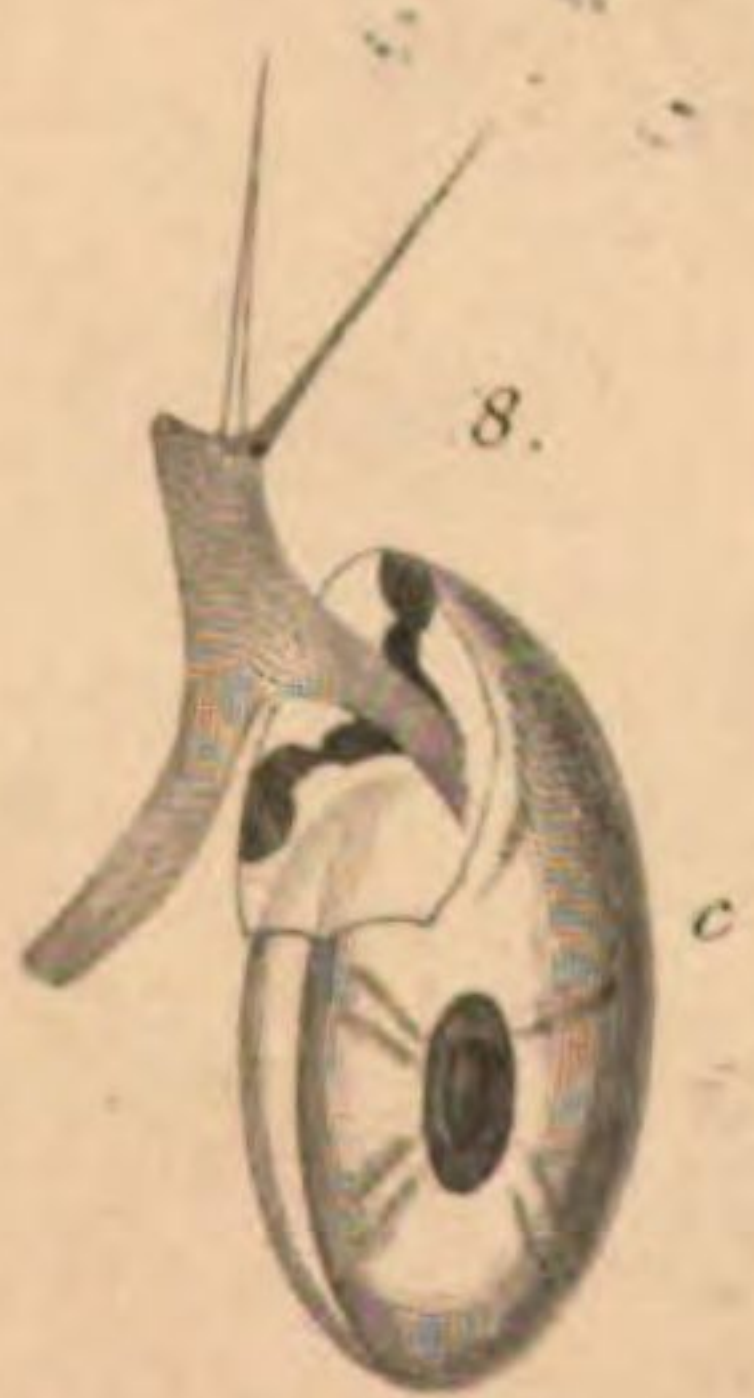
Testacella haliotoidea.



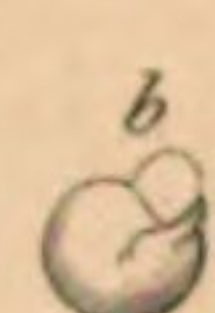
Limnea octona.



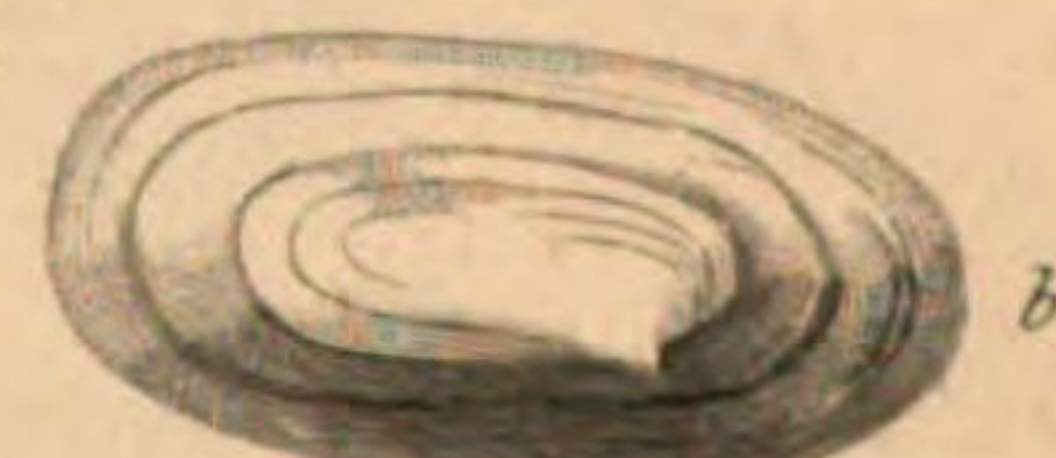
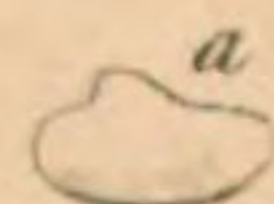
Segmentina lineata.



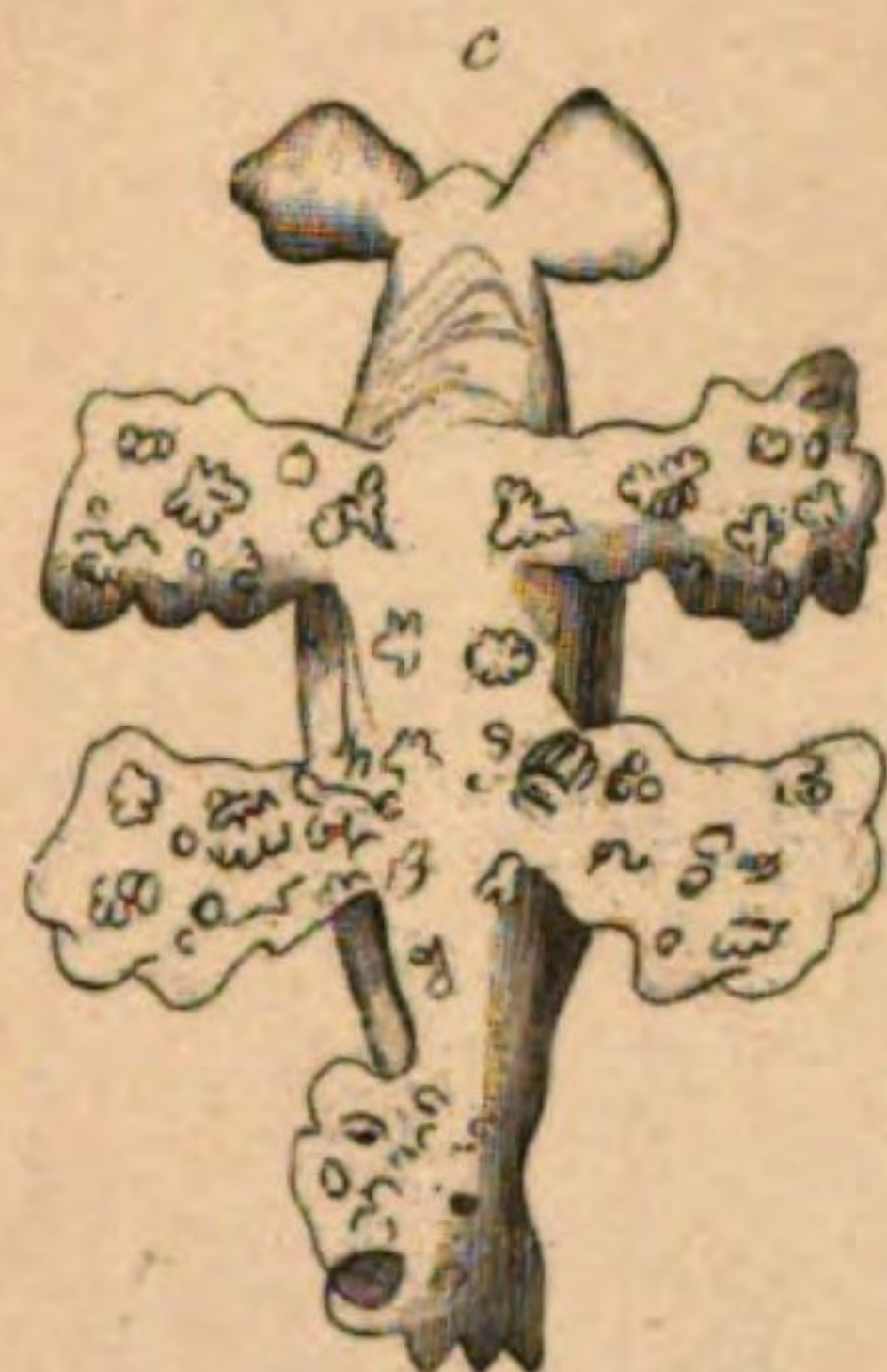
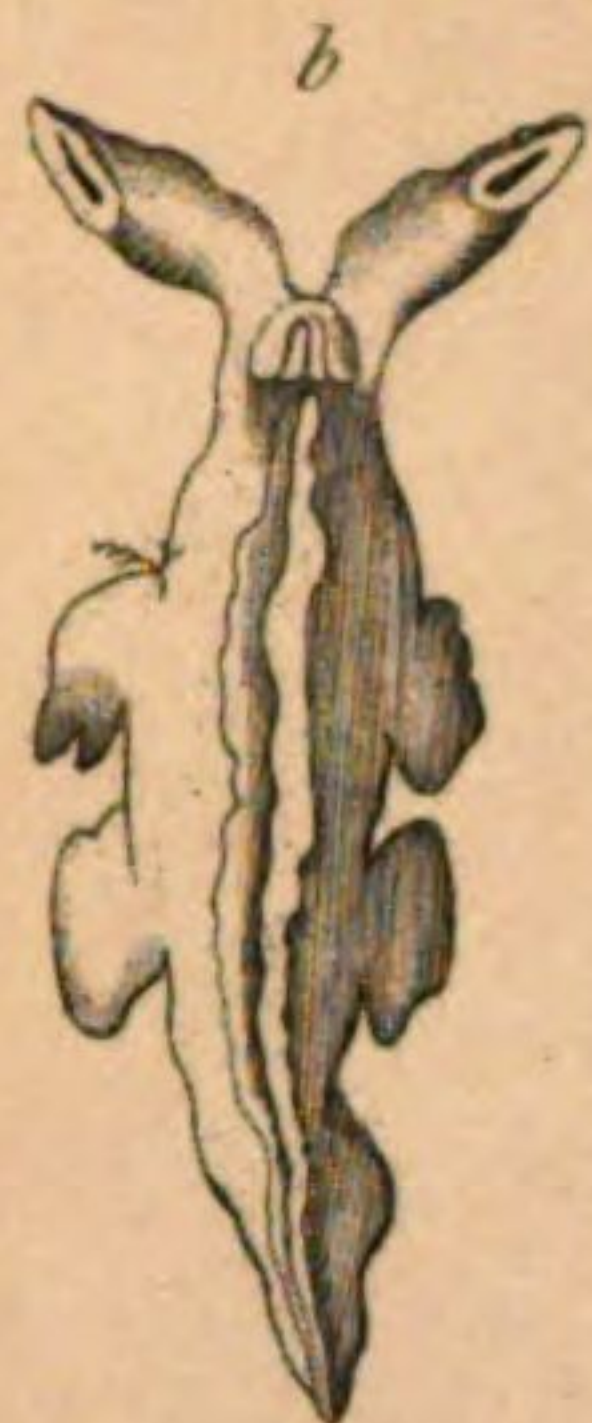
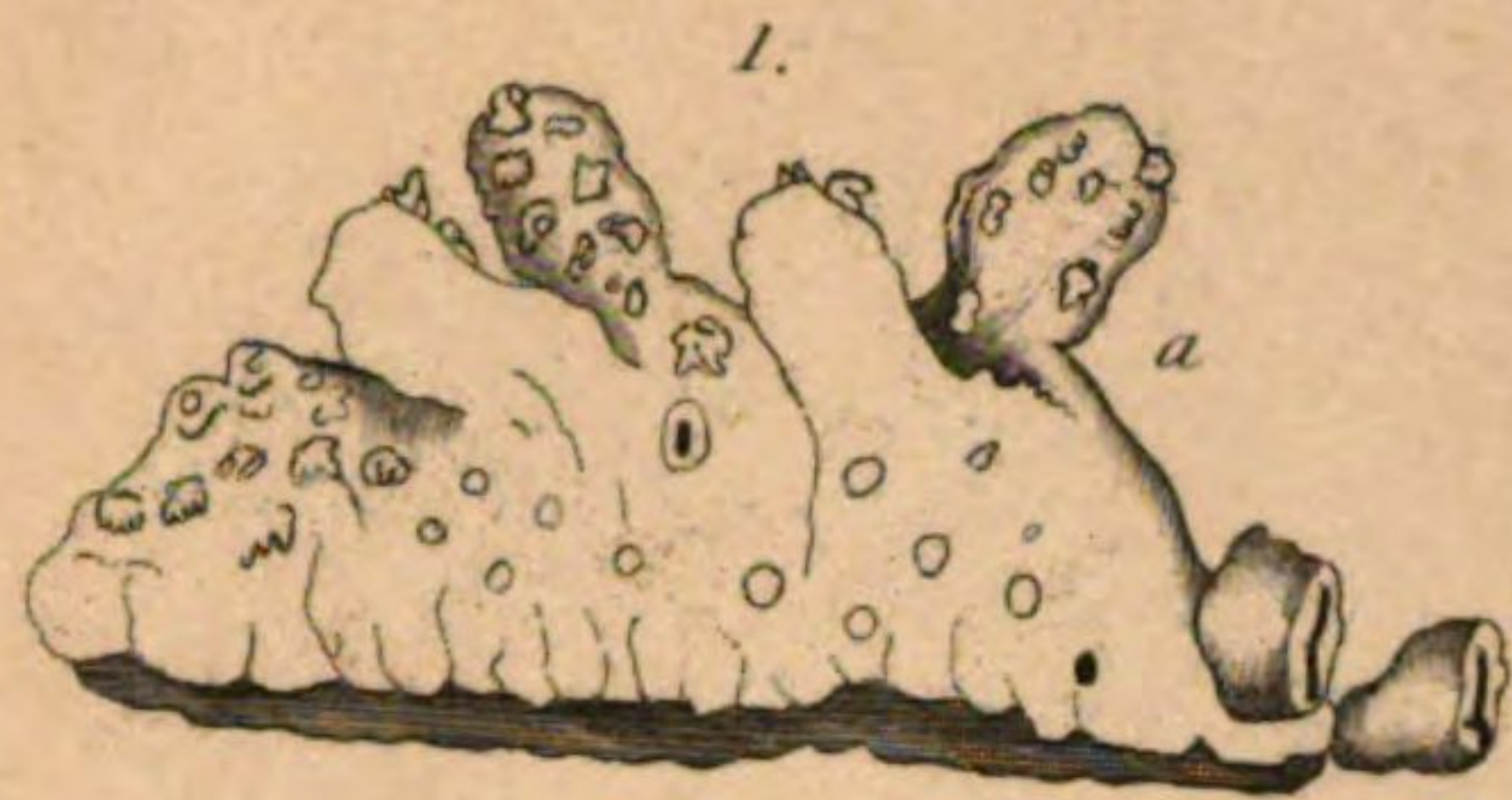
Planorbis nitidus.



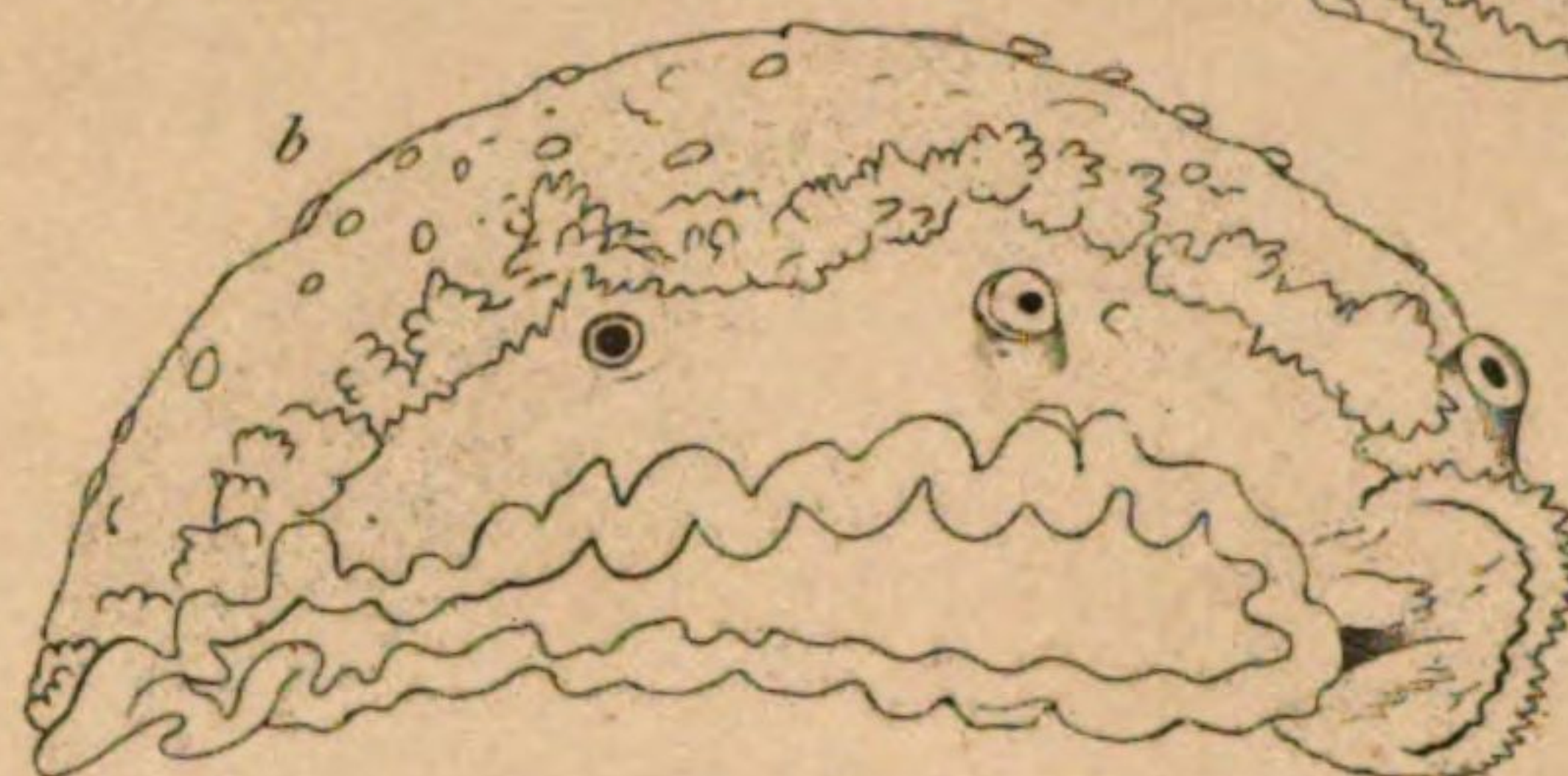
10.



Ancylus lacustris.



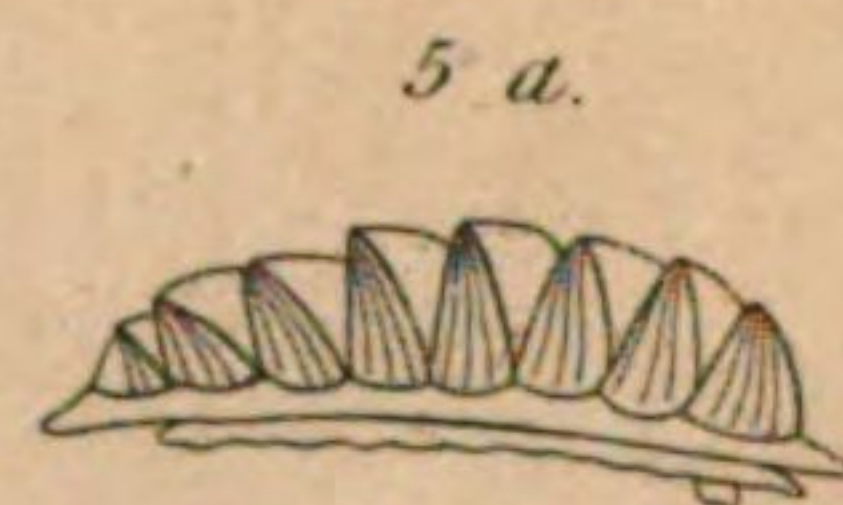
Scyllaea pelagica.



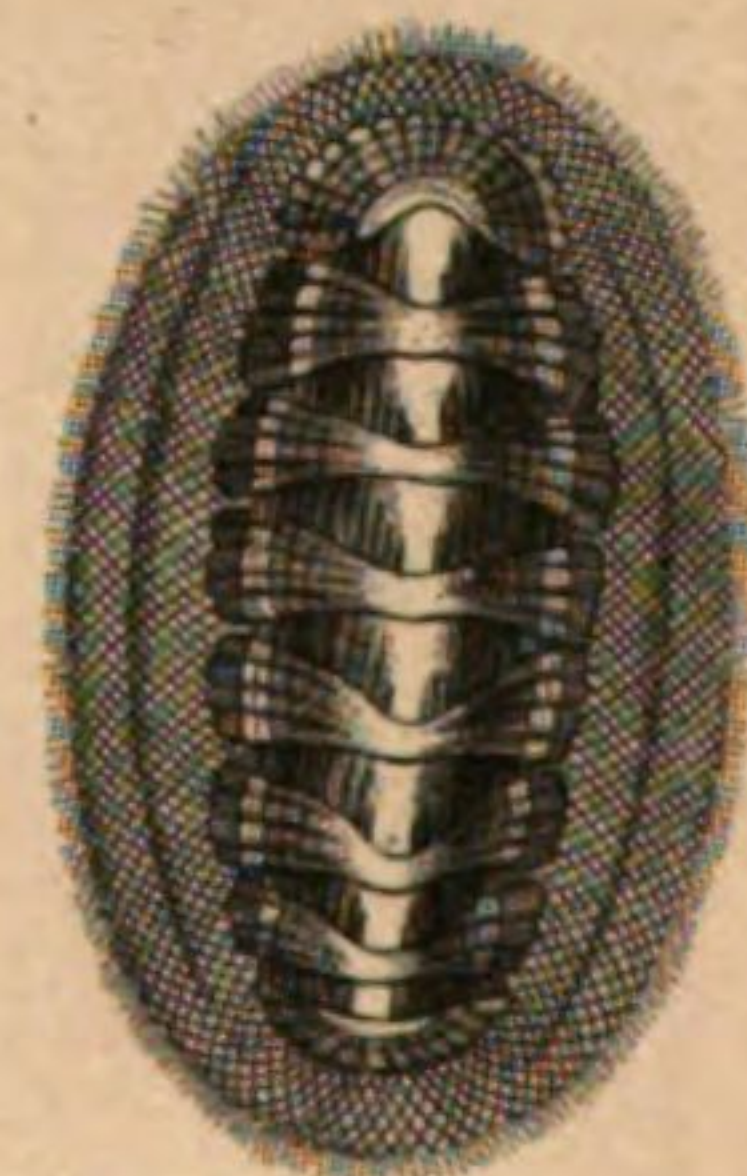
Tritonia Hombergii.



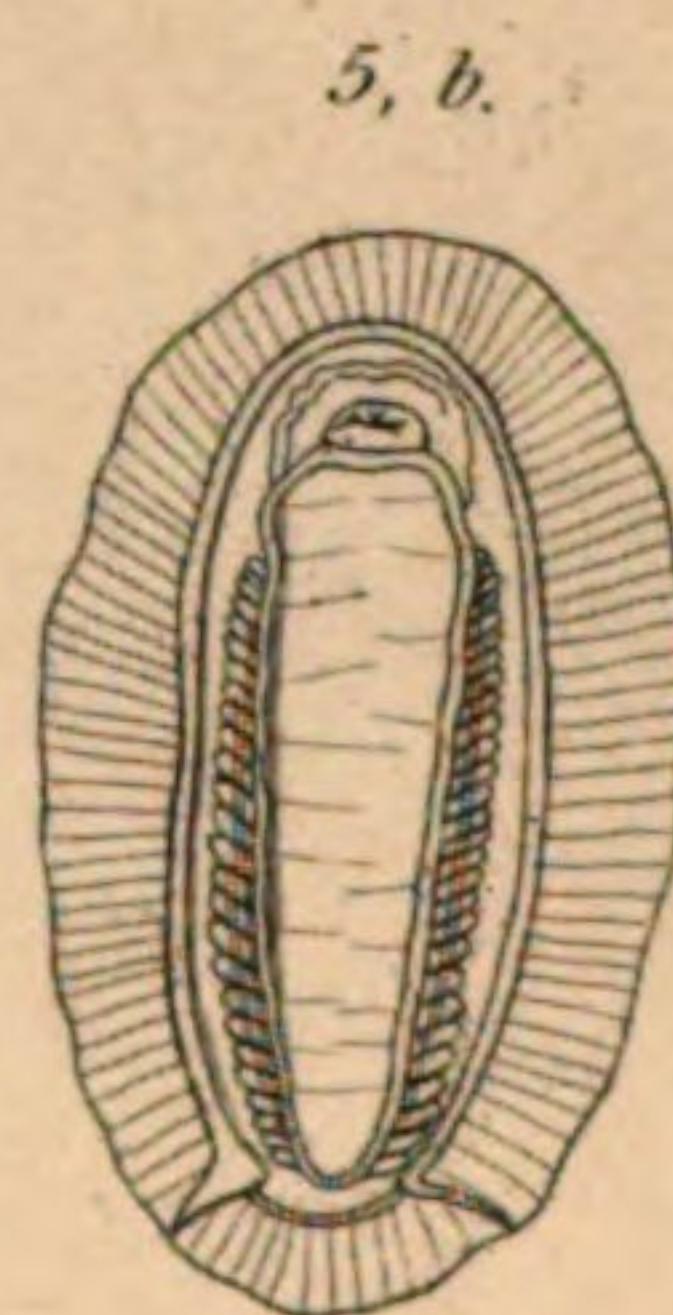
Glaucus radiatus.



5.



Chiton squamosus.



5, c.



Parmophorus australis.



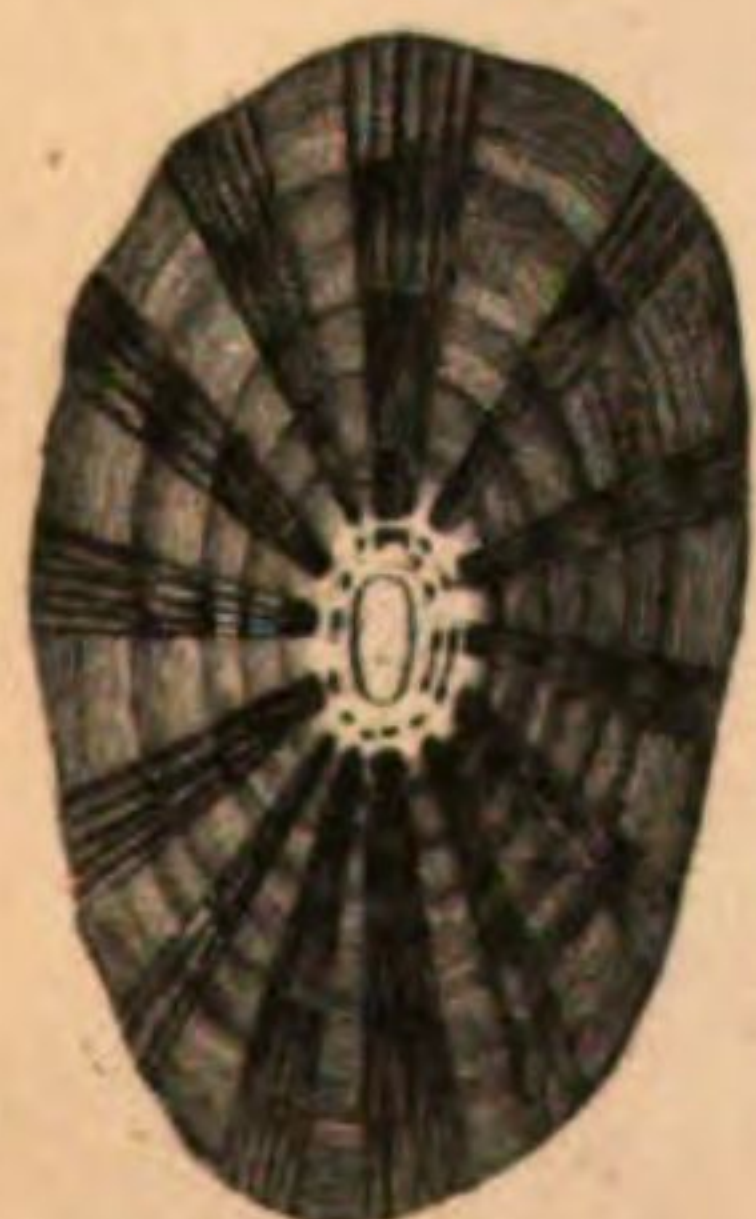
4, a.



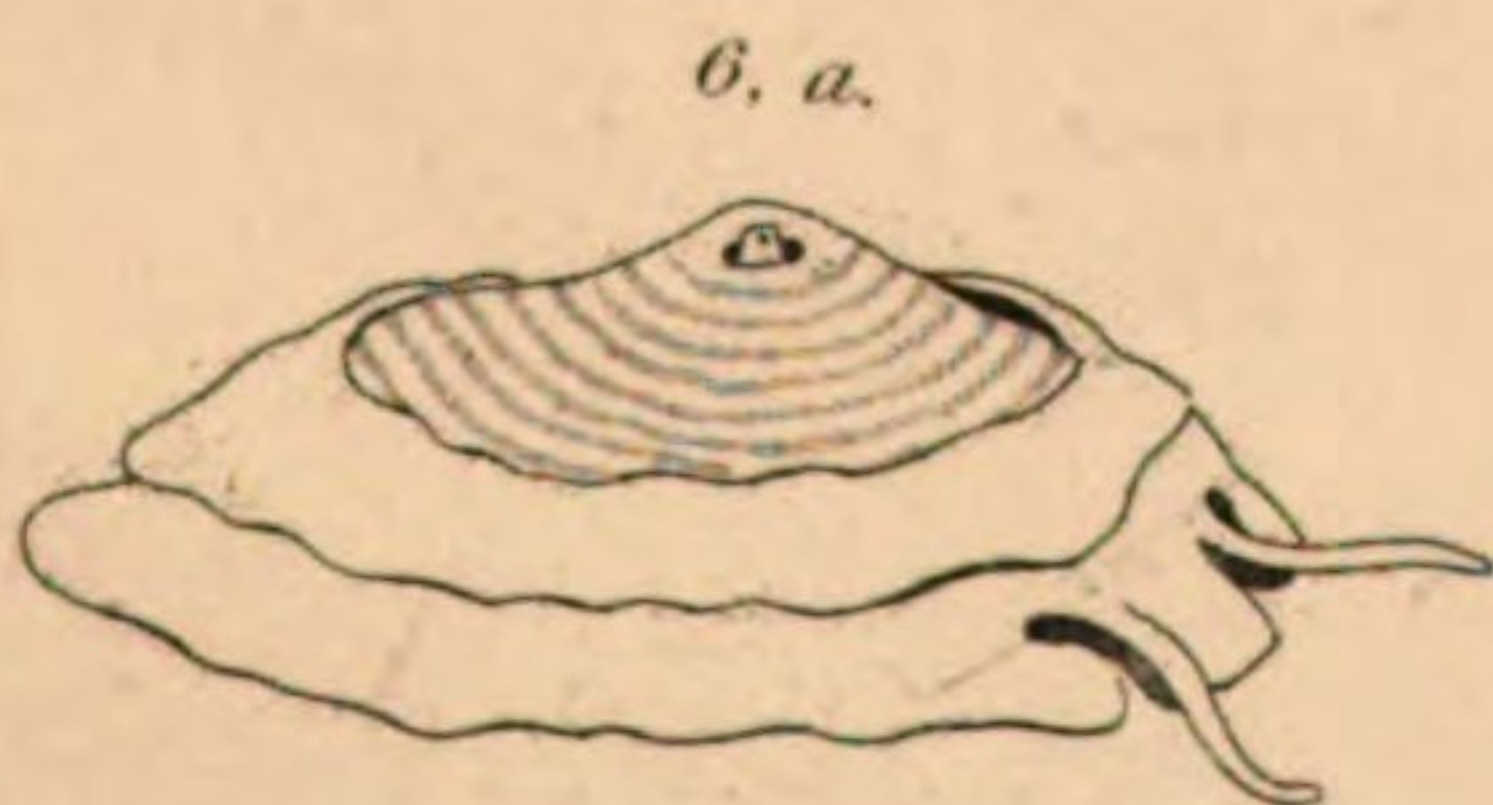
4, b.



Dollabella Rumphii.



Fissurella annulata.



6, a.



8, a.



8.



8, b.



8, c.

Bulla aperta.

Franz Steckeler
Buchbinderel
8384 Höchstädt/Do.

The Encyclopaedia Britannica, or Dictionary of Arts, Sciences, and General
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